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MINERAL LAND CLASSIFICATION: AGGREGATE MATERIALS IN THE FRESNO PRODUCTION-CONSUMPTION REGION

1988

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

SPECIAL REPORT 158

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JAMES F. DAVIS
STATE GEOLOGIST

SPECIAL REPORT 158

MINERAL LAND CLASSIFICATION: AGGREGATE MATERIALS IN THE FRESNO PRODUCTION-CONSUMPTION REGION

1988

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FOREWORD

Special Report 158, "Mineral Land Classification: Aggregate Materials in the Fresno Production-Consumption Region," is the first analysis of mineral resources in the San Joaquin Valley to be developed by the California Department of Conservation, Division of Mines and Geology under authority of the Surface Mining and Reclamation Act of 1975 (SMARA). This classification is provided to the State Mining and Geology Board for transmittal to the local governments that regulate land use in this region, and for consideration of areas, if any, to be designated as regionally significant. SMARA was enacted by the State Legislature to assure mineral resource conservation and adequate mined land reclamation.

The Mining and Geology Board adopted guidelines in June 1978 to be employed by the Division in its mineral resource classification. This report was prepared in conformance with those directives. The undertaking is of great importance in economic geology because it deals with very specific mineral resource conservation issues in areas of intensive competing land use.

James F. Davis
State Geologist

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PREFACE

Reserve tonnage data presented in this report was accurate as of January 1985. In 1986, a preprint version of the report was circulated to lead agencies and made available to the public. Changes in reserves resulting from either the premature closure of mines active in 1985, or the permitting of new mines since that time, may have impacted forecasted depletion dates for the production-consumption region studied. However, the material presented and the fundamental conclusions of the report remain valid and useful.

David J. Beeby
Urban SMARA Program Manager

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Typeface is Times Roman and Futura,
produced by Ad Type Graphics, Inc.

Printing and binding by
Office of State Printing

CONTENTS

	Page
EXECUTIVE SUMMARY	ix
INTRODUCTION	1
Overview of Classification	1
Brief Overview of Designation	2
Overview of Aggregate Uses	2
Background and Purpose	3
DETERMINATION OF THE FRESNO PRODUCTION-CONSUMPTION REGION	4
Transportation Rates	4
ESTABLISHMENT OF THE MINERAL RESOURCE ZONES	5
Areas Classified MRZ-1	6
Areas Classified MRZ-2	7
Areas Classified MRZ-3	7
Areas Classified MRZ-4	8
EVALUATION OF PCC-GRADE AGGREGATE IN THE FRESNO P-C REGION	8
Concepts Used in Identifying Available Aggregate Resource Areas	8
Sectors	8
Resource Sectors within Parks	9
Calculation of Available Resources	9
Reserves and Resources	9
Factors Considered in Calculations	9
Resource Sector Descriptions	9
San Joaquin River Area — Sector S	9
Kings River Area — Sector K	10
Parklands	12
Other MRZ-2 Areas	12
ESTIMATED 50-YEAR CONSUMPTION OF AGGREGATE	13
Basis of 50-Year Forecasts	13
Correlations between Aggregate Production and Consumption	13
Projected Population and Per Capita Consumption through the Year 2034	14
Factors Affecting Per Capita Consumption Rates	14
Comparison of the 50-Year Aggregate Demand with Current Reserves	16
ALTERNATIVE SOURCES OF AGGREGATE	16
Potential Alluvial PCC-Grade Aggregate	16
Potential Crushed Rock Aggregate	17
Potential Sources of PCC-Grade Aggregate Outside the P-C Region	17
CONCLUSIONS	18
ACKNOWLEDGMENTS	18
REFERENCES	19
APPENDIX	21
Interim Criteria for Sectorization of MRZ-2 Areas for Aggregate	21

TABLES

		Page
Table 1.	Lead agencies located within the Fresno P-C Region	4
Table 2.	Minimum rates for transport of aggregate in the Fresno area	5
Table 3.	Aggregate resources in the San Joaquin River	11
Table 4.	Aggregate resources in the Kings River	12
Table 5.	Nonpermitted resources in parklands	13
Table 6.	Summary of resources	13
Table 7.	Population, aggregate consumption and per capita consumption in the Fresno P-C Region during the period 1960-1983	15
Table 8.	Projected aggregate consumption through the year 2034 for the Fresno P-C Region	16
Table 9.	Transport distance from the active deposits nearest the Fresno P-C Region	18

FIGURES

		Page
Figure 1.	General location of the Fresno P-C Region	1
Figure 2.	Index to quadrangles in the Fresno P-C Region	5
Figure 3.	Quadrangle index indicating geologic maps used in classification of the Fresno P-C Region	6
Figure 4.	Generalized columnar section of the stratigraphy in the Fresno P-C Region	7
Figure 5.	Fresno P-C Region: Annual per capita consumption of aggregate, 1960-1983	14
Figure 6.	Fresno P-C Region: Population and aggregate production records, 1960-1983	15
Figure 7.	Projected population, Fresno P-C Region	17

PLATES

Plate 1. Fresno P-C Region
Plate 2. Mineral land classification map of aggregate resources in the Fresno P-C Region

Mineral Land Classification Maps

Plate 3. Lanes Bridge Quadrangle
Plate 4. Friant Quadrangle
Plate 5. Herndon Quadrangle
Plate 6. Fresno North Quadrangle
Plate 7. Piedra Quadrangle
Plate 8. Sanger Quadrangle
Plate 9. Wahtoke Quadrangle

Resource Sector Maps

Plate 10. Lanes Bridge Quadrangle
Plate 11. Friant Quadrangle
Plate 12. Herndon Quadrangle
Plate 13. Fresno North Quadrangle
Plate 14. Piedra Quadrangle
Plate 15. Sanger Quadrangle
Plate 16. Wahtoke Quadrangle

Cross Sections

Plate 17. Sections A-A″ and B-B′
Plate 18. Sections C-C′ and D-D′

EXECUTIVE SUMMARY

This report presents the results of the classification of aggregate resources by the Division of Mines and Geology (DMG) in the Fresno Production-Consumption (P-C) Region. The primary goals of the study were:

1. To delineate within the P-C region all land containing sand and gravel deposits suitable for production as high-quality, Portland cement concrete (PCC) aggregate.
2. To calculate the quantity of the resources in these deposits that are on lands considered by the State to be available for possible aggregate production based upon evaluation of land uses.
3. To evaluate the adequacy of the current aggregate reserves (aggregate resources on land permitted for mining by local government) for meeting the future needs of the P-C region.

In the Fresno area, as in any rapidly urbanizing area, it is important that land-use decisions are made with full recognition of the natural resources of the area. This is especially true when the resource in question is high-grade construction aggregate, an indispensable building material which is costly to transport.

The Fresno area has been fortunate in that adequate quantities of low-cost, high-quality aggregate materials have been available locally. However, the amount of this material is diminishing as active aggregate producers deplete their deposits and land containing suitable sand and gravel resources is utilized for urban development.

The loss of regionally significant mineral deposits to land uses that preclude mining is one of the problems that the California Surface Mining and Reclamation Act of 1975 (SMARA) was framed to address. SMARA mandates a two-phased mineral resource conservation process called classification-designation. The objective of the classification-designation process is to provide information on future resource availability to the urban population centers which depend upon it for future growth. This perspective will hopefully provide a context for land-use decisions by local government within which mineral resource availability is acknowledged as a pertinent factor.

The DMG is responsible under SMARA for carrying out the classification phase of the classification-designation process. Classification of land for aggregate resources in the Fresno area is presented in this report. The State Mining and Geology Board (the Board) is responsible for the second phase of SMARA. In this phase, the Board may designate areas within a P-C region that contain significant deposits of PCC-grade aggregate that may be needed to meet the region's future demand. The Board's decision to designate an area is based upon information in the classification report prepared by DMG and input received from lead agencies and the public. Through designation, the Board provides formal recognition of regionally significant deposits of aggregate resources.

As with many forecasts of economic activity, the forecasts in this report should not be viewed as offering unqualified predictions of how the future will unfold. They are based upon the assumption that the data base is accurate and that the development trends of the past three decades will continue into the five decades ahead.

Assuming, however, the correctness of DMG's forecasts regarding the consumption of aggregate, the following conclusions were reached:

- The consumption of aggregate resources in the P-C region through the year 2034 is forecast to be 268.4 million tons, of which approximately 50 percent or 134.2 million tons must be of PCC quality.
- Unless additional resources are permitted for mining, or alternative resources are utilized, total existing PCC reserves would be depleted by mid-2010.
- More than 119.3 million tons of permitted PCC-grade reserves exist in the P-C region.

- In total, the 119.3 million tons of permitted PCC-grade aggregate reserves could provide only 44 percent of the anticipated consumption of all aggregate during the next 50 years.
- The expected longevity of the existing PCC reserves is based upon the assumption that mining of these reserves will continue to be permitted until the reserves are depleted.
- In excess of 2.1 billion tons of aggregate resources (including reserves) have been identified within the Fresno P-C Region. Twenty-eight million tons of the nonpermitted resources occur in dedicated parklands and are unlikely to be permitted for mining.
- The Fresno P-C Region covers an area of 1,400 square miles, of which 39 square miles (3 percent of the total area) were classified MRZ-2. Only 31 square miles (2 percent of the total area) have been sectorized as having current land uses which do not preclude mining. Almost 3½ square miles of the sectorized areas are currently under mining permits.
- The 31 square miles of sectorized lands considered in this study to be available for meeting future aggregate needs may be greater than the amount local governments consider to be available for mining. The reason for this discrepancy is that sectorized lands may have already been committed by local governments to purposes other than aggregate mining. The significance of this difference of opinion regarding availability is that the projected available resources (as defined by the Board) may be optimistic, and the problem of meeting future aggregate needs could be greater than that described in this report.

It is important, therefore, that local governments promptly review the sector areas shown as available for future aggregate extraction. Local governments will then be able to verify or amend as necessary the conclusions reached in this report.

MINERAL LAND CLASSIFICATION: AGGREGATE MATERIALS IN THE FRESNO PRODUCTION-CONSUMPTION REGION

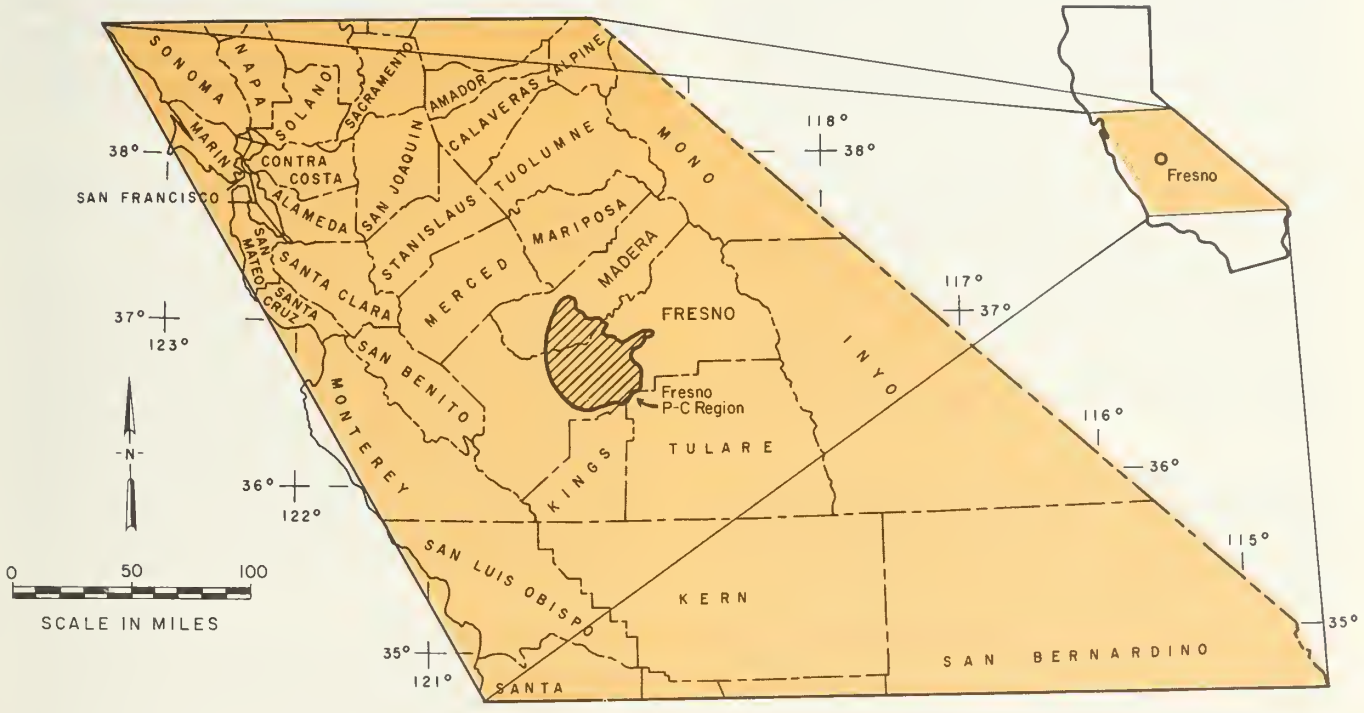


Figure 1. General locotion of the Fresno P-C Region.

INTRODUCTION

In the Fresno area (Figure 1 and Plate 1), as in any rapidly urbanizing area, it is important that land-use decisions are made with full recognition of the natural resources of the area. This is especially true when the resource in question is high-grade construction aggregate used in Portland cement concrete (PCC). This type of aggregate is an indispensable building material and is costly to transport.

The Fresno area has been fortunate in having adequate quantities of low-cost, high-quality aggregate materials locally available. However, the amount of these materials available for future development is diminishing as active aggregate producers deplete their deposits and land containing suitable sand and gravel resources is utilized for urban development.

The loss of access to regionally significant mineral deposits as a result of land uses that preclude mining is one of the problems that the California Surface Mining and Reclamation Act of 1975 (SMARA) was framed to address. SMARA mandates a two-phased mineral resource conservation process called classification-designation. The objective of this process is to establish an awareness of the availability of important resources to urban population centers through communication with the appropriate lead agencies regarding the location and significance of mineral deposits within their region.

Overview of Classification

The DMG is responsible under SMARA for carrying out the classification phase of the classification-designation process. Classification entails six distinct but interrelated steps. These six steps are described below.

1. *Determination of Production-Consumption (P-C) Region Boundaries.* The boundaries of the P-C region are drawn along the limits of the marketing area of the active aggregate operations supplying the urban center under study.

The Fresno area was chosen for study as an urban center anticipated by the State Office of Planning and Research (OPR) to experience expansion. The marketing area of the production sites supplying Fresno was determined by interviews of aggregate operators and analysis of the transport rates set by the Public Utilities Commission (PUC).

2. *Establishment of Mineral Resource Zones (MRZ).* All lands within the Fresno P-C Region are assigned Mineral Resource Zone classifications (MRZ-1, MRZ-2, MRZ-3, or MRZ-4) based upon a geologic appraisal of the aggregate resource potential of the land. This appraisal includes study of pertinent geologic reports and maps, field investigation and sampling at outcrops and at active and inactive pits and quarries, and analysis of water-well logs and drill records.

3. *Identification of Available Aggregate Source Areas as Sectors.* Lands containing significant deposits of PCC-grade sand and gravel (areas classified MRZ-2 in step 2) are evaluated to determine whether or not current uses of these lands preclude possible future mining. Areas currently permitted for mining and areas found to have land uses compatible with possible future mining are considered available for mining. Sectors which identify available land are delineated and described in detail. Criteria for sectorization of MRZ-2 areas, established by the Board, are given in the Appendix.

4. *Calculation of Resource Tonnages within Sectors.* Investigation and analysis of on-site conditions, measurement of the areal extent of deposits, drill-hole information, waste-material percentages, and deposit densities are used to calculate total tonnages of PCC-grade aggregate *reserves* (deposits in land owned by an aggregate producer and permitted for mining by local government at the end of 1984) and *resources* (all deposits of PCC quality, including the reserves) within each sector. Calculations generally reflect conditions of the deposits at the end of 1984, so resource depletion since that time has not been considered.

5. *Forecast of 50-Year Needs and the Life Expectancy of Current Reserves.* The total tonnage of aggregate needed to satisfy demand in the Fresno P-C Region over the next 50 years is estimated based on a comparison of the projected population over that period with the average annual per capita rate of total aggregate consumption from 1960-1983. Even though all identified reserves are of PCC quality, other aggregate commodities are routinely produced and marketed from them. The projected life expectancy of the reserves is based on the assumption that this practice will continue. Results of this forecast are used to determine the life expectancy of the P-C region's current reserves.

6. *Identification of Alternative Resources.* Alternative sources of aggregate to meet the forecast 50-year demand are identified and briefly considered.

Brief Overview of Designation

The present report is concerned with the classification phase of the two-step process mandated by SMARA. The designation phase, the second phase of the SMARA process, follows receipt and acceptance of this classification report by the State Mining and Geology Board. Based upon the sector descriptions provided by DMG, and input from local lead agencies and the public, the Board may adopt regulations which "designate" certain mineral resource deposits as being regionally significant to satisfy future needs. Such designation, if made, would be included as part of state policy.

Overview of Aggregate Uses

Sand, gravel, and crushed stone are "construction materials." These commodities, collectively referred to as aggregate, provide bulk and strength to Portland cement concrete, asphaltic concrete, plaster and stucco. Aggregate is also used as road base, subbase, railroad ballast, and fill. Aggregate normally provides from 80 to 100 percent of the material volume in the above uses.

Aggregate material is essential to the needs of a modern society. It is a resource of great importance to the economy of any metropolitan area.

During 1983, about 2.7 million tons of aggregate, an amount worth between $10 and $11 million, were mined from the San Joaquin River and Kings River deposits in the Fresno P-C Region. Nearly 95 percent of this amount was consumed within the P-C region, and there are no known imports of PCC-grade aggregate into the region. Approximately 50 percent of the aggregate produced from 1960 to 1982 was used as Portland cement concrete aggregate (U.S. Bureau of Mines statistics). Enormous tonnages of high-quality PCC-grade aggregate are used in concrete highways, dams, canals, airport runways, bridge abutments, foundations, buildings, and general construction.

In this aggregate resource classification study, special emphasis is given to aggregate that meets the specifications used in making Portland cement concrete. The material specifications for PCC-grade aggregate are more restrictive than the specifications for aggregate for other applications. The restrictiveness of these specifications makes deposits acceptable for use as PCC aggregate the scarcest and most valuable of aggregate resources. This also means that aggregate produced from such deposits can be and is commonly used in applications other than concrete. Because of its versatility, its value, its importance in construction, and its relative scarcity, PCC-grade aggregate deposits are of the most concern when planning for the future availability of aggregate commodities.

In past years, the population in the Fresno area has been served by high-quality, relatively low-cost aggregate deposits from the San Joaquin and Kings rivers. However, the high-quality deposits are rapidly being depleted, and many of the potential sources are becoming inaccessible as urbanization encroaches on lands once used solely for mining and agriculture.

Rarely, even from the highest-grade deposits, is in-place aggregate raw material physically or chemically suited for every type of aggregate use. Every potential deposit must be tested to determine how much of its material can meet specifications for a particular use and for what processing is required. Specifications for various uses of aggregate material have been established by several agencies, such as the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and the California Department of Transportation (Caltrans), to ensure that aggregate is satisfactory for specific uses. These agencies and other major consumers of concrete test aggregate for acceptance by standard test procedures outlined by such organizations as

the American Society for Testing Materials and the American Association of State Highway Officials.

Most aggregate specifications have been established to ensure the manufacture of strong, durable structures capable of withstanding the physical and chemical effects of weathering and use. For example, specifications for Portland cement concrete and concrete products prohibit or limit the use of rock materials containing mineral substances such as gypsum, pyrite, zeolites, opal, chalcedony, chert, siliceous shale, volcanic glass, and some high-silica volcanic rocks. Gypsum shortens the setting time of Portland cement, pyrite dissociates to yield sulfuric acid and an iron oxide stain, and other substances contain silica in a form that reacts with alkali substances in the cement, resulting in cracks and "pop-outs."

Specifications also call for precise particle-size distributions for the various uses of aggregate. Aggregate is commonly classified into two general sizes: coarse aggregate and fine aggregate. Coarse aggregate is rock retained on a 3/8″ or a #4 U.S. sieve. Fine aggregate passes a 3/8″ sieve and is retained on a #200 U.S. sieve (a sieve with 200 weaves per inch). For some uses, such as asphalt paving, particle shape is specified. Caltrans Standard Specifications (1981) require that at least 25 percent by weight of coarse aggregate (1/4 inch to 3/4 inch diameter) used as Class 2 aggregate base material shall be crushed particles. Furthermore, aggregate material used with bituminous binder to form sealing coats on road surfaces shall consist of at least 90 percent by weight of crushed particles. Crushed stone is preferable to natural gravel in asphaltic concrete because asphalt adheres better to broken surfaces than to rounded surfaces, and the interlocking of angular particles strengthens the asphaltic concrete and road base.

The preferred use of one aggregate material over another in construction practices depends not only on specification standards, but also on economic considerations. Alluvial gravel is preferred to crushed stone for Portland cement concrete aggregate because the rounded particles of alluvial sand and gravel result in a mix that is easier to work than a mix composed of angular fragments. The workability of a mix consisting of Portland cement with crushed stone aggregate can be improved by adding more sand, water, and cement which must be added to the mix to maintain concrete durability standards. At the present time, the additional cement amounts to about a quarter of a 94 pound sack per cubic yard of concrete at an additional cost of about $0.75 per yard of mix. Although more care is required in pouring and placing mix containing crushed stone, Portland cement concrete made with this aggregate is as satisfactory as that made with alluvial sand and gravel of comparable rock quality.

In the Fresno area, PCC aggregate sells in bulk for about $4.00 per ton at the plant site (in mid-1984). However, this selling price reflects only part of the costs to the consumer. Transport costs are a significant part of the final delivery price. In areas that lack nearby aggregate sources, the delivery charges alone may be greater than the sale price of the material at the plant site.

Background and Purpose

Urban expansion has been a major contributing factor to the loss of significant mineral resources in past years. In response to the problem of conflicting land use, the need for essential mineral products and for information concerning their location and quantity, the California State Legislature enacted the Surface Mining and Reclamation Act of 1975. SMARA requires the State Geologist to classify,* according to the presence or absence of significant mineral deposits, certain areas of the state which are subject to urban expansion or other irreversible land uses incompatible with mining. Urbanizing areas are identified by the State Office of Planning and Research. The boundaries of the areas are modified to reflect current land use through consultation with local lead agencies and selected on-site field inspection.

The State Mining and Geology Board, upon receipt of the classification information from the State Geologist, transmits the classification report to the appropriate lead agencies and makes it available to other interested parties. Upon receipt of the classification report, each lead agency must develop and adopt mineral resource management policies to be incorporated in its general plan within 12 months. These policies will:

1. Recognize the mineral classification information, including the classification maps, transmitted by the Board.
2. Emphasize the conservation and development of identified mineral deposits.

After receipt of mineral classification information from the State Geologist, the State Mining and Geology Board may designate specific geographic areas that contain mineral deposits of regional significance. Procedures for the designation** of lands containing significant mineral deposits are specified in Section II.2 of the State Mining and Geology Board's "Guidelines for Classification and Designation of Mineral Lands," which is included as Part II of California Division of Mines and Geology Special Publication 51, "California Surface Mining and Reclamation Policies and Procedures" (1983). This publication is available free from the Division of Mines and Geology.

The objective of the classification and designation process is to ensure, through appropriate lead agency policies and procedures, that raw material is available when needed and does not become inaccessible as a result of a lack of information during land-use decision-making actions.

The "Guidelines for Classification and Designation of Mineral Lands" were adopted by the State Mining and Geology Board on June 30, 1978. The purpose of the guidelines is to implement SMARA by providing direction to the State Geologist in carrying out mineral resource classification, and to establish procedures by which the Board may designate mineral-bearing lands of statewide or regional significance. Section 1.1.a of the guidelines requires that the State Geologist classify specified areas into *Mineral Resource Zones* (MRZ) or *Scientific Resource Zones* (SZ) as defined in Section I.2 of the guidelines. Although California has a wide range of mineral commodities within its

---

*Classification is the process of identification of lands containing significant mineral deposits based solely on geologic factors, and without regard for present land use or land ownership.

**Designation is the formal recognition by the State Mining and Geology Board, after consultation with lead agencies and other interested parties, of areas containing mineral deposits of regional or statewide significance that should be considered for protection from land uses incompatible with mineral extraction. These deposits are deemed to be of prime importance in meeting the future needs of the region or the state.

borders, the State Mining and Geology Board recognizes that construction materials (sand, gravel, and crushed stone) are produced regionally, are used in every urban area of the state, and require special classification data. Section I.3 of the guidelines requires that classification reports that pertain to deposits of construction materials include the following information: (1) the location and estimated total quantity of construction material that is geologically available for mining; (2) limits of the market (production-consumption) region which the potential resource would serve; and (3) an estimate of the total quantity of material that will be needed to supply the requirements of the consumption region for the next 50 years. This information will assist the State Mining and Geology Board in determining the statewide or regional significance of these types of deposits.

The Mineral Land Classification of the Fresno Production-Consumption Region was initiated in 1984 by the State Geologist. Included in the project area are parts of Fresno and Madera counties. Portland cement concrete-grade aggregate resources of the area were selected for initial classification.

Each aggregate deposit was evaluated separately, and then considered as part of a single production-consumption region established on the basis of existing aggregate consumption patterns. The Fresno marketing region is served by two production districts with overlapping market regions, the San Joaquin River production district and the Kings River production district.

DETERMINATION OF THE FRESNO PRODUCTION-CONSUMPTION REGION

The city of Fresno was targeted by the Office of Planning and Research as an area experiencing significant urban expansion (OPR, 1975), and the State Mining and Geology Board scheduled it for an aggregate study by the Division of Mines and Geology. To determine the aerial limits of such a study, the Division must accommodate several factors. Ideally, both the production districts and 95 to 100 percent of the areas served by these districts are included in this study. Usually, this more than encircles the area identified by the OPR as that anticipated to be urbanized by 1990. This is the case in Fresno.

A study of sand and gravel production and consumption showed that all aggregate used in the urbanizing portions of Fresno County is produced from the San Joaquin and Kings rivers. (The only other active deposit within Fresno or Madera counties is adjacent to Los Gatos Creek, north of Coalinga. It serves an area within a 30-mile radius of the deposit site and so does not contribute aggregate to the city of Fresno.)

It was found that aggregate consumption, though centered on the city of Fresno, reaches outward, encircling an area within a 20-mile radius. Thus the production-consumption region was delineated (Plate 1), encompassing: (1) the entire metropolitan area of Fresno, Clovis and Sanger and surrounding areas anticipated by the OPR and/or the local lead agency to urbanize in the next 10 to 30 years; (2) outlying towns such as Madera, Selma, and Kingsburg; (3) rural areas not anticipated to urbanize but which are sparsely populated and consume aggregate from the San Joaquin and Kings rivers; and (4) the two resource areas. The eastern boundary of the area roughly matches the break in slope between the foothills and the Sierra Nevada Mountains and follows census tract boundaries to allow use of existing census and other population data for forecasting. Lead agencies with jurisdiction within the P-C region are shown on Table 1.

Transportation Rates

Because aggregate is a low-value, high bulk-weight commodity, a major part of the cost of aggregate to the consumer is for transportation. In fact, transport costs are one of the major constraints on the marketing area for a production district.

All aggregate marketed in the Fresno P-C Region is transported by truck. Minimum rates for independent aggregate truckers are set by the California Public Utilities Commission. Rates for the Central Valley are published in "Minimum Rate Tariff 7-A," sections 1 through 3 and supplement 24. Charges are calculated based on either an hourly rate or a distance rate. If the hourly rate is used, the carrier and debtor must enter into a written agreement prior to transport.

TABLE 1. Lead agencies (counties and incorporated city governments) located within the Fresno P-C Region.

AGENCIES	
CITIES	COUNTIES
Clovis	Fresno* +*
Kingsburg	Madera* +*
Madera	
Reedley	
Sanger	
Selma	
Fresno* +*	

* Agencies with active aggregate operations within their jurisdictional boundaries.
+ Agencies that have land classified MRZ-2 within their jurisdiction.
* Lead agencies containing sectors.

Table 2 contains the distance rates for selected increments and the hourly rates, as specified in Minimum Rate Tariff 7-A. Increasing the distance between a production area and a market area will increase the consumer's cost. Hauling aggregate from Coalinga to downtown Fresno (approximately 60 miles), for example, would result in a transport cost greater than the product cost. Total cost per delivered ton of PCC aggregate would increase from around $5.50 per ton to around $10 per ton.

TABLE 2. Minimum rates for transport of aggregate in the Fresno area.

DISTANCE RATES* (for selected increments)		HOURLY RATES**	
MILES	RATES ($/ton)	NO. OF AXLES PER UNIT OF EQUIPMENT	RATES ($)
11	1.55	2	37.00
21	2.49	3	41.50
31	3.39	4	43.00
41	4.27	5+	46.90
52	5.23		
63	6.08		
80	7.50		
85	7.89		

* includes November 1984 increase in surchorge; rates are higher for wark dane an holidays ar weekends and if equipment ather than a "... tractar with battam dump daubles in train" are required at the destinatian.

**current as af July 9, 1984; rates are higher for wark dane an halidays and weekends.

ESTABLISHMENT OF MINERAL RESOURCE ZONES

The DMG has classified land in the Fresno P-C Region according to the presence or absence of significant PCC-grade aggregate deposits. The land classification is presented in the form of Mineral Resource Zones or MRZ s. Directions for the identification of Mineral Resource Zones are set forth in DMG's Special Publication 51 in the section entitled "Guidelines for Classification and Designation of Mineral Lands" (CDMG,1983).

The guidelines for establishing the Mineral Resource Zones are as follows:

MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence. This zone shall be applied where well-developed lines of reasoning, based upon economic-geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is nil or slight.

MRZ-2 Areas where adequate information indicates that significant mineral deposits are present, or where it is judged that a high likelihood for their presence exists. This zone shall be applied to known mineral deposits or where well-developed lines of reasoning, based upon economic-geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is high.

MRZ-3 Areas containing mineral deposits, the significance of which cannot be evaluated from available data.

MRZ-4 Areas where available information is inadequate for assignment to any other mineral resource zone.

Mineral Resource Zones in the Fresno P-C Region are presented on a Mineral Resource Zone map (Plate 2) and on seven U.S. Geological Survey topographic maps (Plates 3-9) that cover in detail those areas classified MRZ-2. Figure 2 shows the quadrangle maps that cover the Fresno area.

Figure 2. Index of U.S. Geological Survey quadrangles covering the Fresno P-C Region; the detailed Minerol Lond Classificotian maps (Plates 3-9); Resource sector maps (Plotes 10-16); and, the P-C region baundary. Urbanized and urbonizing portions of the P-C regian are shawn with the stippled pattern.

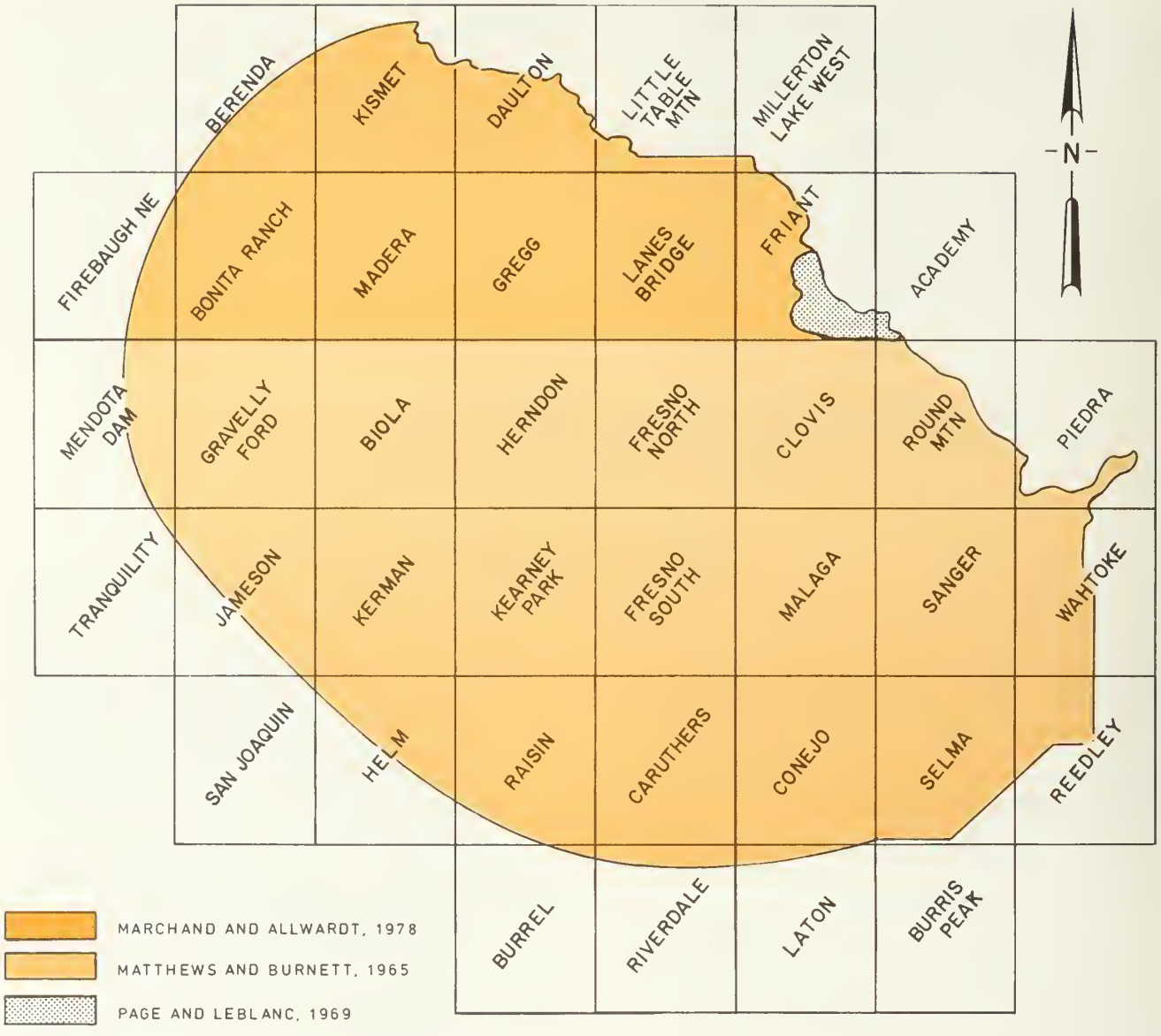


Figure 3. Quadrangle index indicating geologic maps used in classification of the Fresno P-C Region.

Mineral resource zones within the Fresno P-C Region were established on the basis of an aggregate appraisal that included the following tasks for assessing the quantity, quality, and extent of the aggregate deposits:

1. Examination and compilation of relevant geologic maps, aerial photos, geologic literature, aggregate industry data (some of which is proprietary) and aggregate engineering test data. The geologic maps used in classification of the Fresno P-C Region are indicated on Figure 3.
2. Interviews with aggregate operators, company geologists, and consultants.
3. Compilation and analysis of subsurface well-log data and drilling records.
4. Field investigation of active and depleted aggregate quarries.

Areas Classified MRZ-1

Areas classified MRZ-1 were judged on the basis of available data to have little likelihood of containing significant deposits of PCC-grade aggregate. Deposits that have excessive amounts of clay, silt, organic matter, absorptive rock, alkali-reactive rock, platy rock, or soft rock are unsuitable for use in PCC aggregate; areas containing such deposits are classified MRZ-1.

The areas in the Fresno P-C Region that are classified MRZ-1 (see Plate 2) are underlain by alluvial material judged to contain too much clay, silt, tuffaceous or pumiceous sediments. These include Quaternary basin deposits in the center of the San Joaquin Valley and the Friant Pumice Member of the Turlock Lake Formation which crops out on both sides of the San Joaquin River in the Friant, Lanes Bridge, and Millerton Lake West quadrangles (Marchand and Allwardt, 1978). The location of

the basin deposits was determined from a compilation of all three maps listed on Figure 3. Additionally, areas depleted of gravel and reclaimed as ponds or landfill are also classified as MRZ-1. Land falling in the latter category is present within the floodplains of both the San Joaquin and Kings rivers.

Areas Classified MRZ-2

Two areas within the Fresno P-C Region are classified as MRZ-2 (see Plate 2). These are areas for which data indicate that there is a high likelihood that significant deposits of PCC-grade aggregate exist.

SMARA guidelines set forth two requirements to be used to determine if land should be classified as MRZ-2:

1. The deposit must be composed of material that is suitable as a marketable commodity.
2. The deposit must meet threshold value. The projected value (gross selling price) of the deposit, based on the value of the first marketable product, must be at least $8,500,000 (which is equal to 5 million 1978 dollars).

Areas classified MRZ-2 contain aggregate resources that are either proven PCC-grade or highly likely to be of PCC-grade. Much of the aggregate in the MRZ-2 areas has not been identified as PCC-grade aggregate through formal engineering tests. Aggregate deposits in untested, unproven areas identified as MRZ-2 are believed to contain PCC-grade aggregate for either of the following reasons:

- The aggregate in unproven areas is similar in age and lithology, and was deposited under similar geologic conditions to that of the proven PCC-grade aggregate.
- The unproven deposit is a lateral extension of an alluvial formation from which PCC-grade aggregate has been produced.

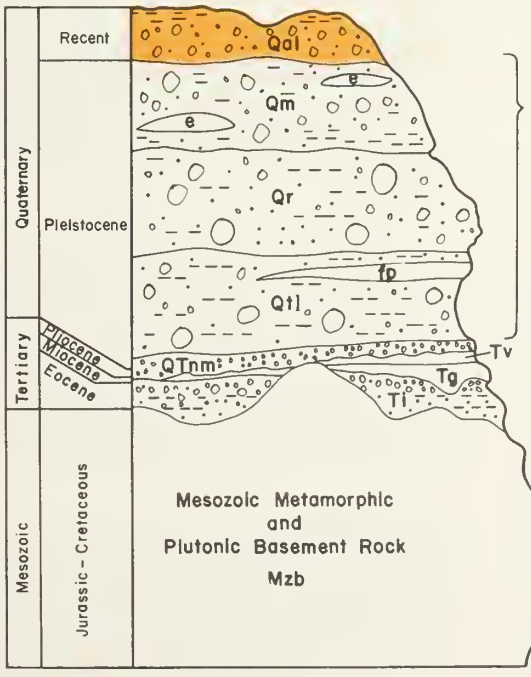
Areas classified MRZ-2 in the Fresno P-C Region are underlain by Holocene river channel and floodplain deposits. These include parts of the San Joaquin River floodplain from Herndon to Lost Lake, and the Kings River floodplain from Central Avenue to Avocado Lake.

Areas Classified MRZ-3

Areas classified MRZ-3 are those containing aggregate deposits, the significance of which cannot be evaluated from available data.

Sedimentary, metamorphic, and igneous rock types are often included in this category. Positive indications in the geologic literature, and a petrologic field examination that shows a rock unit to contain abundant, hard, durable material without excessive amounts of deleterious materials are necessary for a unit to be considered a suitable candidate for an MRZ-3 classification. Additional information regarding the quality of material in these areas could either upgrade the classification to MRZ-2 or downgrade the classification to MRZ-1. Formations and rock types located within the Fresno P-C Region that are classified MRZ-3 include (see Figure 4): the Ione Formation, an unnamed Tertiary basalt and gravel unit, the North Merced Gravels (Marchand and Allwardt, 1978), and metasedimentary and granodioritic rocks of the Sierra Nevada Mountains (Matthews and Burnett, 1965).

A large percentage of the areas classified MRZ-3 in the Fresno P-C Region are located in the San Joaquin Valley and are



Qal: Basin, river channel and alluvial depasits. Alluvial sand, silt and gravel deposited in terraces, fans and basins. Deposition is hypothesized to have occurred during, and was controlled by, glaciation in the Sierra Nevada Mountains (1) and (2).

Qm: Madesta Formation

e: eolian depasits

Qr: Riverbank Formation

Qtl: Turlock Lake Formation

fp: Friant Pumice Member

QTnm: North Merced pediment gravels

Tv: variously described as olivine basalt (3) or trachyandesite (4)

Tg: pre-volcanic gravels deposited by San Joaquin River

Ti: Ione Formation - strongly indurated and cemented sandstone and conglomerate with clay interbeds. Primarily fluvial

Mzb: Basement rocks within the Fresno P-C Region consist of pre-Cretaceous metasedimentary rocks, granodiorite and granite. (5)

1) Janda, 1965
2) Marchand, 1977
3) Marchand and Allwardt, 1978
4) Marchand and Allwardt, 1981
5) Matthews and Burnett, 1965

Figure 4. Generalized columnar section of the stratigraphy in the San Joaquin River area.

composed of Quaternary alluvial deposits. Though these sediments were deposited under similar conditions and derived from the same source rocks as those classified MRZ-2, they are older and have undergone too much weathering to consistently meet the specifications for MRZ-2. An exploration and testing program, however, might locate areas of PCC-grade material within these sediments. Stratigraphic relationships of these units are shown on Figure 4.

Portions of the San Joaquin and Kings rivers floodplains (see Plate 2) were classified MRZ-3, due to a variety of factors. In some cases, these areas have been previously mined and the remaining quantity of aggregate could not be shown to meet the minimum threshold value stipulated in SMARA. Other portions of the floodplains were classified MRZ-3 due to the size gradation of the deposits. The aggregate upstream of Avocado Lake (Kings River) is composed of oversized clasts. The aggregate downstream of Highway 99 (San Joaquin River) and in the vicinity of where the Kings River floodplain narrows (Plate 8), contains a significant amount of sand and fine sand. Exploration may allow these deposits to be utilized in Portland cement concrete.

Areas Classified MRZ-4

Areas classified MRZ-4 are those areas for which available information is lacking or incomplete for assignment into the other MRZ categories. No areas were classified MRZ-4 in the Fresno P-C Region.

EVALUATION OF PCC-GRADE AGGREGATE IN THE FRESNO P-C REGION

An assessment of aggregate resources in the Fresno P-C Region is presented in this section of the report. The assessment was conducted on the basis of a quantitative evaluation of available and suitable aggregate resources classified MRZ-2.

Concepts Used in Identifying Available Aggregate Resource Areas

The State Geologist is responsible for calculating aggregate resources for those areas classified MRZ-2. Recognizing that there are lands within MRZ-2 areas that have already been urbanized and that, therefore, have a limited opportunity for mineral resource conservation and extraction, the State Geologist has limited the calculation of aggregate resource tonnages to portions of MRZ-2 areas that have not been urbanized.

For purposes of classification, incompatible uses are urbanized lands containing high-cost improvements such as high-density residential developments, intensive industrial developments, commercial developments, and major public facilities (see Appendix, Interim Criteria for Sectorization of MRZ-2 Areas for Aggregate). Compatible uses are nonurbanized land comprised of very low density residential land (approximately one unit or less per ten acres), recreational land that does not have high-cost improvements, agricultural land, silvicultural land, grazing land, and open space.

For this report, the determination of which MRZ-2 land is nonurbanized was based upon conditions of the land at the time of the study (January 1984 through October 1984). The use of the land was determined by the authors after consultations with lead agencies, reference to aerial photographs and photo-revised topographic maps, and field reconnaissance.

SECTORS

Sectors are areas that have been classified MRZ-2 by the State Geologist, and that are deemed to be available for mining based upon criteria for availability provided by the State Mining and Geology Board.

A sector is an area within which the geometrical configuration of the deposit is sufficiently regular to permit reliable calculation of the tonnage of the mineral resource present. Thus, for example, sector boundaries would be established between that part of a natural deposit formed on a fan, and that part within the confines of an adjacent modern stream channel and its floodplain. Mineral land classification, which is done without regard for current land use, results in a delineation of the resource areas on maps, but this by itself does very little to put into perspective the resource base that is available to meet the future needs of a region. Sectors have been employed to focus the attention of land planners and local governments on just those areas that remain accessible for mineral extraction. The State Geologist calculates the available resources of each sector, and identifies the amount of remaining resources that have been permitted for mining. These latter resources are termed reserves. The resources present in other (non-sectorized) MRZ-2 resource areas are not calculated because they are regarded as unavailable.

The calculated reserves and resources of all the sectors of a region are compared with the State Geologist's forecast of the 50-year needs of a region for the mineral resources. The comparison of regional needs with the available reserves and resources provides the opportunity to focus attention on the mineral resource issues confronting the region; *viz.*, the need to plan carefully for the use of any lands containing mineral resources and the need to consider the permitting of additional mining operations in the region as currently mined deposits are depleted.

Each sector meets or exceeds the Board's threshold values for deposits of significant size, and each sector may be considered for designation as an area of regional or statewide significance by the State Mining and Geology Board pursuant to Section 2790 SMARA. Areas that have not been sectorized by the State Geologist are not considered for designation by the Board.

Although the classification by the State Geologist and the designation by the Board are actions explicitly provided for by SMARA, and although the results of such actions yield reports

that must be acted upon by affected local governments, the sectorization and sector maps do not in and of themselves carry with them specific obligations imposed on local governments by SMARA.

The sector maps and the resource base calculations, however, contain the essential facts that are needed to focus the attention of planners on the mineral availability problems and the alternative solutions to meet the mineral resource needs of the region. Without the sector maps and the accompanying calculations, the primary objectives of SMARA could not be achieved.

Because the Board's criteria for sectorization focus on the apparent suitability of the land for mining and do not take into account commitments that may have been made to restrict the accessibility of some of the sectors for mining, it is possible that the available resource base as calculated by the State Geologist may be overestimated and the problems confronting local government may be understated. Considering these possibilities, it becomes important for local governments to carefully review the sectors and the associated estimates of resources to ensure that previously unrevealed problems are not overlooked and that planning decisions are made using a correct perspective on available resources.

RESOURCE SECTORS WITHIN PARKS

Dedicated parklands are recognized as having a special status. Resource sectors within parks have, therefore, been treated as a special class of sectors, and the quantifications of the resources in them are presented separately in Table 5.

Calculation of Available Resources

RESERVES AND RESOURCES

In this report, *reserves* are estimates of tonnages of aggregate that have been determined to be acceptable for commercial use that exist within properties owned or leased by aggregate producing companies, and for which permits have been granted to allow mining and processing of the material. *Resources* include *reserves* as well as all similar potentially usable aggregate materials that may be mined in the future, but for which no permit allowing mining has been granted.

FACTORS CONSIDERED IN CALCULATIONS

The resource estimates given here are limited to those PCC-grade aggregate resources present in resource sectors, which are, as explained in the previous section, the nonurbanized portions of the areas classified MRZ-2. The resource sectors defined in this study are shown on the sector maps (Plates 10-16) that accompany this report.

The sectors are subdivided into numbered subsectors to recognize the location of existing freeways, canals, bridges, dams, major powerlines, and major pipelines. These criteria allowed for the calculation of more realistic resource tonnages. Subsectors S-1 through S-20 identify resource areas in the San Joaquin River; Subsectors K-1 through K-32 delineate resource areas in the Kings River.

The following factors were used to determine the areal extent and tonnage of PCC-grade aggregate resources within the sectors:

1. Sector resource tonnage estimates for the Kings River were based on measurements taken from base maps that have a scale of 1:24,000. Estimates for the San Joaquin River were based on aerial photogaphs that have a scale of 1:9,600.
2. Even in proven PCC-grade aggregate deposits, a small percentage of the aggregate cannot be used in concrete and is referred to in this study as "waste." Waste includes pit-run and production waste, both of which may be utilized in non-PCC uses, primarily as fill. Known waste percentages were extrapolated to deposits in untested sector areas from proven, nearby PCC-grade deposits.
3. Thicknesses of PCC-grade deposits were determined through use of water-well log data and information provided by persons who have knowledge concerning aggregate deposits and exploration in this region.
4. Typical setbacks from utility and rail lines, urban developments and roads, as stipulated in lead agency mining ordinances, were used in determining the areal limits of sectors that border areas not available for mining.

Resource Sector Descriptions

The total area of the resource sectors in the Fresno P-C Region is 31 square miles, of which almost 3½ square miles are currently permitted for mining. As previously noted, sectors are delineated only within areas classified MRZ-2 and that are available for mining. The estimated total of PCC-grade aggregate resources in these sectors is 2.17 billion tons (29 million tons of which is in dedicated parklands). As of November 1985, 119.3 million tons of these resources were permitted for mining, and therefore qualified as reserves. Annual depletion of reserves for 1985 has not been subtracted from this figure.

The resource sectors are described below:

SAN JOAQUIN RIVER AREA — SECTOR S

The San Joaquin River has provided PCC-grade aggregate since the early 1920s. The earliest mining occurred in the upstream portion of the river, near the town of Friant. Lost Lake, just west of Friant, was formed by the excavation of aggregate used in the construction of Friant Dam (completed in 1934). PCC-grade aggregate was also mined as far downstream as one mile west of Highway 99. Mining from this area ceased in the mid-1960s. Both areas still contain some high-quality aggregate. However, it could not be shown that the remaining aggregate resources meet the minimum threshold value established by the Board; thus, they are classified MRZ-3. The remainder of the downstream portion of the floodplain within the P-C region is also classified MRZ-3. This portion is composed predominantly of sand and could not, with the available information, be proven to be coarse enough for PCC-grade aggregate. However, this area undoubtedly contains a large volume of sand.

Six companies process aggregate from the San Joaquin River for use in Portland cement concrete, asphaltic concrete, road base, plaster sand, fill, etc. River Rock Products has two sites, one near Herndon (Sectors S-2a and S-2b, Plates 12 and 13) and another on Old Friant Road (Sectors S-10a and S-10b, Plate 10). Stewart and Nuss has a large part of the floodplain permitted between Scout Island and Highway 41 (Sectors S-5a, S-5b, S-5c, and S-6, Plate 13) and has been active at this

site since 1963. However, the company may not be allowed by the landowner to completely mine that part of its lease which lies south of the river and west of the highway. River Rock Products is active only in Fresno County, whereas Stewart and Nuss has permits in both Fresno and Madera counties.

San Joaquin Rock and Sand, the next producer upstream, is active only in Madera County (Sectors S-7a and S-7b, Plates 10 and 13). This company's lease and permitted area is located just west of Highway 41 on the northern side of the river. The company has been active here for a little over two years, having obtained the plant from a prior operator. Brueckner Sand and Gravel (Sector S-8, Plate 10) has been working on a 29-acre area adjacent to Rice Road since 1974.

Sequoia Rock Company's lease abuts the northern line of River Rock Products on Old Friant Road (Sectors S-11a and S-11b, Plate 10). The company also controls Cobbs Island and "Island No. 1" in Madera County (Sector S-14, Plate 10). North from Sequoia Rock along the Friant Expressway is Lonestar Industries' rock plant (Sector S-16, Plate 11). The plant was built prior to 1960, and most of the land surrounding it has been mined. Lonestar is currently mining from a new permit in subsector S-19 (Plate 11). The landowners of the northern half of subsector S-19 (Plate 11) have also obtained a conditional use permit, but nearby homeowners have a lawsuit pending against the permit.

No unusual specialty products are sold from the San Joaquin River deposits. However, secondary gold recovery is occurring at most aggregate plants.

None of the individual rock clasts contained in either the sand or gravel fractions of the deposits classified MRZ-2 contain minerals deleterious to the production of PCC-grade aggregate.

Between 40 and 60 percent of the rock clasts within the San Joaquin River between Herndon and Friant are composed of medium- to coarse-grained granitic rock types: granite, granodiorite and quartz monzonite. This includes rocks with these compositions but with a gneissoid texture or with the addition of secondary chlorite and epidote. Clasts of diorite and gabbro were rarely observed. Metamorphic rock types, such as amphibolite, schist, phyllite and slate, compose 5 to 10 percent of the clasts. Another 10 percent consists of very hard, well-lithified conglomerate derived from metasedimentary units in the Sierra Nevada Mountains or from outcrops of the Ione Formation in Little Table Mountain. Volcanic and metavolcanic clasts compose another 10 to 20 percent. These consist mostly of fine-grained to porphyritic basalt or andesite, scoriaceous basalt, or welded light-colored tuffs. Quartzite clasts and various other rock types compose the remainder of the clasts. The sand fraction is composed of quartz, biotite, and rock fragments with occasional grains of epidote and pumice. The latter is probably derived from reworking of the Friant Pumice Member of the Turlock Lake Formation which crops out in the river bluffs north of Copper Avenue. All the sediments are subrounded to rounded and oblong to spherical in shape.

Aggregate from the San Joaquin River is mined from a floodplain which developed throughout late Pleistocene to Recent time, in fact, probably until completion of the Friant Dam. The characteristics of the deposit seem to vary along the length and width of the floodplain. For instance, on Ledger Island (Plate 4 or 11) bedrock of the Sierra Nevada batholith comes within 15 feet of the surface. A northwest trending fault mapped through the older alluvium, concealed by the Recent deposits (Marchand and Allwardt, 1978) north of Ledger Island, may be the reason for this shallow occurrence of the bedrock in the river channel.

The production zone consists of a gravel-rich layer which, where present, varies in thickness from 15 to 59 feet. Below the gravel-rich layer is a clay layer which varies in thickness from 1 foot to more than 20 feet thick (the bottom of the clay layer has not been found when it is this thick). On a portion of the Stewart and Nuss lease, the gravel layer was at one time totally excavated, leaving the top of the clay daylighted. The latter appeared to be terraced in three distinct levels (personal communication with Stewart and Nuss personnel). The cause of the terracing is unknown. This clay is described by the operators as being hard, and they have mostly found it infeasible to excavate through it to any underlying gravels. However, there are a few exceptions to the occurrence of this clay layer. Excavation for aggregate at what is now Lost Lake is said to have extended 60 to 70 feet below the ground surface. Obviously the clay layer either did not occur here or was of such minimal thickness and hardness that it was ignored. Similarly, the clay layer is said to be a foot or less in the Brueckner pit, allowing mining to occur to a greater depth.

As would be expected, the floodplain deposits generally become finer as one moves downstream. The maximum clast size near Friant is 10 inches, whereas downstream near Herndon, it is 4 inches. However, not far downstream from Friant, on land leased to Lonestar Industries, there are areas where gravel does not exist and the fine size of the sand is believed to make it infeasible for the deposit to be mined (personal communication with Lonestar employees). This area is classified MRZ-3 (Plate 4). It is unknown if there are other areas with this anomalous size-gradation.

Most of the operators use 1.5 tons per cubic yard as a rule of thumb for in-place density. However, Stewart and Nuss cites 1.8 tons per cubic yard for the density of their reserves. It is not known if this company has better data than the other operators or if the deposit really is denser in their area. The higher density value was used for subsectors containing their leases (see Table 3).

The other factors used in calculating resource tonnages also vary, due to the variability of the San Joaquin River deposit. The estimates of percent waste, production-zone and overburden thickness and, as previously noted, in-place density were based on field observations and information supplied by active producers, and occasionally on water-well logs. This information was extrapolated to sectors without active or historic mining from adjacent and geologically similar sectors where data was available.

KINGS RIVER AREA — SECTOR K

The Kings River is geomorphically similar to the San Joaquin River except that it has a broader floodplain and a thicker section of Recent sand and gravel. Unlike the San Joaquin River, a persistent underlying clay layer has not been reported by the operators nor described in water-well logs.

There are only two operators currently producing aggregate from the Kings River. Central Valley Ready Mix is located adjacent to Annadale Road, with the aggregate plant south of the road and their current mining site north of the road (Sectors K-18

and K-11b, Plate 15). The company began operating in 1945. Sanger Rock and Sand began in the late 1940s at their site south of Highway 180 and east of Trimmer Springs Road (Sectors K-10a and K-10b, Plate 16). Both companies process aggregate for use in PCC and asphaltic concrete. Industrial Asphalt used to mine aggregate from a site along the river just north of Goodfellow Avenue. However, the company abandoned this site several years ago.

Aggregate was excavated from the area that is now Avocado Lake, southwest of Piedra, for use in Pine Flat Dam which was completed in 1954. Just upstream of Avocado Lake the floodplain of the Kings River consists mainly of boulders. These large-sized clasts are difficult to work with and hard on mining and processing equipment. Therefore, this area was classified MRZ-3. Conversely, where the river turns southward and the floodplain narrows (Plate 9), water-well logs indicate that gravel no longer occurs in the subsurface. Due to the lack of gravel, these more distal deposits are classified MRZ-3, but sand of PCC-grade might be found here with an exploration program. Maximum clast size within the area classified MRZ-2 varies from 12 inches near Avocado Lake to 5 inches at the intersection of Trimmer Springs Road and Belmont Road to 2 inches near the southern part of the MRZ-2 area. Clasts are rounded to well-rounded and oblong to spherical in shape.

Due to the smaller number of producers on the Kings River, less is known about the variability of production-zone and overburden thickness than on the San Joaquin River. The factors used in resource calculations were obtained from the two active producers and from selected logs of water wells. Waste was assumed to be 15 percent, and in-place density 1.5 tons per cubic yard in all subsectors. The production-zone thickness, which varies between 25 and 80 feet as shown in Table 4, was determined from water-well logs.

As with the rock clasts in the San Joaquin River, no minerals deleterious to the production of PCC-grade aggregate were found in the Kings River deposits.

Granitic rock types compose the majority of clast types observed at localities along the Kings River. Plutonic rocks more intermediate in composition, such as diorite, constitute a greater portion of the deposit than on the San Joaquin River. Ultramafic rock types, such as peridotite and serpentine, were also found. The majority of the remainder of the deposit appears to be composed of quartzite, fine-grained basaltic volcanic rocks, and fine-grained metavolcanic rocks of various compositions.

Both the San Joaquin and the Kings rivers are dammed just upstream from the P-C region. This means that neither is re-

TABLE 3. Aggregate resources in the San Joaquin River, Fresno and Madera counties.

SECTOR	NONPERMITTED RESOURCES (tons)	PERMITTED RESOURCES (reserves) (tons)	TOTAL ACRES IN SECTOR	PRODUCTION-ZONE THICKNESS (feet)	WASTE (%)
S-1	14,400,000		179	35	2
S-2a	0	**	27	**	**
S-2b	6,500,000	**	213	30	2
S-3	9,600,000		168	25	3
S-4	6,300,000		111	25	3
• S-5a	6,000,000		225	25	3
• S-5b	0	**	31	**	**
• S-5c	0	**	38	**	**
• S-6	0	**	218	**	**
S-7a	3,500,000	**	159	16	4
S-7b	0	**	23	**	**
• S-8	9,400,000	**	209	20	3
S-9	4,400,000		122	16	4
S-10a	0	**	30	**	**
S-10b	7,400,000	**	355	25	2
S-11a	0	**	12	**	**
S-11b	31,700,000	**	824	25	5
S-12	2,300,000		43	25	2
S-13	2,300,000		42	25	2
S-14	0	**	225	**	**
S-15	16,400,000		360	20	3
S-16	0	**	51	**	**
S-17	1,300,000		39	15	5
S-18a	500,000		23	10	5
S-18b	500,000		25	10	5
S-19	0	**	532	**	**
* S-20				30	5
TOTAL	122,500,000	***	4,284		

* Parklands — see Table 5
• In-place density estimated to be 1.8 tons per cubic yard; resources in all other sub-sectors calculated using a density of 1.5 tons per cubic yard
** Proprietary
*** See Table 6 for combined reserves total for the San Joaquin and Kings rivers.

ceiving bed load recharge and the deposits are not being replenished. Another important point is that once a pit is abandoned, and allowed to refill with water, it is not economically feasible (today) to re-open the pit and resume the mining of any remaining gravel. This fact should be considered before closing down operations at one site and permitting another.

PARKLANDS

In the Fresno P-C Region two parks have been sectorized. China Creek Park (Subsector K-31) constitutes 120 acres within the Kings River floodplain. It is currently unimproved land which serves as a wildlife sanctuary, though improvements are planned. Subsector S-20 consists of a portion of the Fresno County Park at Lost Lake. This area contains river and lake frontage, picnic tables, lawn and shade trees, and restrooms. Resource volumes calculated within these two subsectors are given in Table 5.

Other MRZ-2 Areas

Specific sites of current, on-going production of aggregate for use in other applications than PCC may also be classified MRZ-2. The production level for these sites must be significant enough to be reported to the U.S. Bureau of Mines. No such sites have been found in the Fresno P-C Region.

TABLE 4. Aggregate resaurces in the Kings River, Fresna County (Percentage of waste is assumed ta be 15 and density 1.5 tans per cubic yard in all sub-sectars).

SECTOR	NONPERMITTED RESOURCES (tons)	PERMITTED RESOURCES (reserves) (tons)	TOTAL ACRES IN SECTOR	PRODUCTION-ZONE THICKNESS (feet)
K-1	27,200,000		237	60
K-2	15,100,000		129	60
K-3	33,000,000		287	60
K-4	15,000,000		137	60
K-5	61,600,000		462	70
K-6	23,200,000		198	60
K-7	3,500,000		27	80
K-8	29,600,000		192	80
K-9	15,700,000		105	80
K-10a	82,400,000	**	516	80
K-10b	19,200,000	**	118	80
K-11a	11,200,000		87	80
K-11b	13,700,000	**	106	80
K-12	195,500,000		1,190	80
K-13	48,900,000		410	60
K-14	27,900,000		540	30
K-15	38,600,000		637	30
K-16a	128,100,000		1,076	60
K-16b	5,800,000		49	60
K-17a	19,200,000		165	60
K-17b	65,600,000		562	60
K-17c	15,900,000		136	60
K-18	86,500,000	**	554	80
K-19	237,100,000		1,499	80
K-20	179,800,000		1,130	80
K-21	42,100,000		422	50
K-22	46,100,000		570	40
K-23	21,400,000		271	40
K-24a	8,300,000		84	50
K-24b	51,100,000		516	50
K-25	49,000,000		399	60
K-26	188,300,000		1,349	70
K-27	11,900,000		237	25
K-28	51,200,000		457	55
K-29	16,900,000		280	30
K-30	8,200,000		138	30
*K-31				80
K-32	5,300,000		49	60
TOTAL	1,899,100,000	***	15,321	

*Park lands — see Table 5
**Proprietary
***See Table 6 for combined reserves total for the San Joaquin and Kings rivers.

TABLE 5. Nonpermitted resources in parklands.

S-20 — Lost Lake County Park (Fresno County)	
Tons = 10,300,000	Acres = 158
assumptions: 1) suitable aggregate zone = 30 feet; 2) waste = 5%; 3) density = 1.5 tons/cubic yard)	
K-31 — China Creek Park (Fresno County)	
Tons = 18,300,000	Acres = 120
assumptians: 1) suitable aggregate zone = 80 feet; 2) waste = 15%; 3) density = 1.5 tons/cubic yard)	
TOTAL TONS = 28,600,000	
TOTAL ACRES = 278	

TABLE 6. Summary of PCC-Grade aggregate resaurces campared with the estimated 50-year demand (all aggregate types): Fresna P-C Region.

Nonpermitted Resources	
San Joaquin River	
Fresno County	70,300,000
Madera County	52,200,000
Kings River	1,899,100,000 tons
Permitted Resources (Reserves)	
San Joaquin and Kings rivers	119,300,000 tons
TOTAL	2,140,900,000 tons
Resources (nonpermitted) in Parklands (Sectors S-20 and K-31)	28,600,000 tons
GRAND TOTAL	2,169,500,000 tons
50-year demand	268,400,000 tons

ESTIMATED 50-YEAR CONSUMPTION OF AGGREGATE

Basis of 50-Year Forecasts

The State Mining and Geology Board, as specified in CDMG Special Publication 51 in the section entitled "Guidelines for Classification and Designation of Mineral Lands," (CDMG, 1983) requires that mineral land classification reports for regions containing construction materials classified as MRZ-2 include "An estimate of the total quantity of each such construction material that will be needed to supply the requirements of both the county and the marketing region in which it occurs for the next 50 years. The marketing region is defined as the area within which such material is usually mined and marketed. The amount of each construction material mineral resource needed for the next 50 years shall be projected using past consumption rates adjusted for anticipated changes in market conditions and mining technology." In the "Guidelines" the Board also specifies that these estimates be reviewed periodically (every 10 years or less).

Fifty-year forecasts of PCC-grade aggregate needs in the Fresno P-C Region were made on the basis of reported aggregate production records during the years 1960-1983. For the purpose of this study, P-C region boundaries were defined to ensure that nearly all PCC-grade aggregate produced in the Fresno area will be consumed in the study area,[1] and that imports of PCC-aggregate from outside the study area are insignificant.

[1]Nearly 95 percent of all aggregate produced in the Fresno P-C Region is consumed within the P-C region baundaries.

Correlations Between Aggregate Production and Consumption

Past studies of aggregate marketing regions in California have shown that there is a strong correlation between the amount of aggregate produced and the population in a given aggregate production-consumption region. On this basis, aggregate production and population figures in the Fresno P-C Region were correlated for the years 1960 through 1983. Correlations between the annual aggregate production records and the population statistics were used to obtain per capita consumption rates of aggregate in the study area. The historical aggregate production data in the study area was obtained from mining records of the U.S. Department of the Interior, Bureau of Mines (1960 to 1983). The historical population data for the Fresno area were taken from the 1980 census data, obtained from Fresno and Madera counties.

The average per capita consumption rate in the Fresno P-C Region is 7 tons of aggregate per year over the period from 1960 to 1983 (see Table 7 and Figure 5). Due to the erratic variations in aggregate production from year to year (see Figure 6), a three-year moving average of the annual aggregate production was used in conjunction with population statistics (for purposes of curve smoothing) to compute the per capita consumption rates for the P-C region. The moderately high consumption rates in the Fresno area are characteristic of aggregate marketing regions in which the overall population density is relatively low and the rate of urban development is high. A moderately high consumption rate probably will be maintained within the Fresno

P-C Region until the onset of urban maturity, then it will decrease and eventually drop to a general maintenance level. Urban maturity is the point in the development of an area at which construction materials are used primarily to maintain what has already been developed, rather than to provide for further development.

Projected Population and Per Capita Consumption through the Year 2034

A simple analysis of the historical aggregate production and population statistics was conducted to forecast basic trends in the per capita consumption rate of aggregate within the Fresno area through the year 2034. The total aggregate needs of the study area through the year 2034 were calculated on the basis of two factors: (1) a projected average annual per capita consumption rate of 7 tons (the average per capita consumption rate for the years 1960 to 1983); and (2) the projected population of the region for future years through the year 2034. Population projections for the years 1980 to 2020 (Figure 7) were obtained from the California Department of Finance (1983). This data was extrapolated by DMG for the study area on a straight line basis through the year 2034 to provide the 50-year population projection as specified under the SMARA guidelines. The results of these calculations (Table 8) reveal that an estimated 268 million tons of aggregate will be needed to satisfy the projected future demand for this construction material in the Fresno P-C Region through the year 2034. Of this total, 134 million tons must be of PCC grade.

Factors Affecting Per Capita Consumption Rates

The wide variations from year to year in the per capita consumption rate (Table 7) (4.97 to 8.44 tons per year) are probably reflections of changes in urban growth rates with time, and the construction of major facilities (for example, freeways). In part, these variations also result from incomplete and inaccurate production records supplied to the U.S. Bureau of Mines. Certainly the economic climate is a powerful variable that influences the annual per capita consumption rates for aggregate. Very high interest rates, for example, such as existed in California during the 1980 to 1982 period, tend to lower the amount of new construction in an area and consequently lower the demand for aggregate.

At some point in the future, the average annual per capita consumption rate of 7 tons for the Fresno P-C Region will probably decrease with the onset of urban maturity and then stabilize at a lower rate. However, should unforeseen events occur, such as massive urban renewal, disaster reconstruction, or a major recession, the per capita consumption rate could change radically.

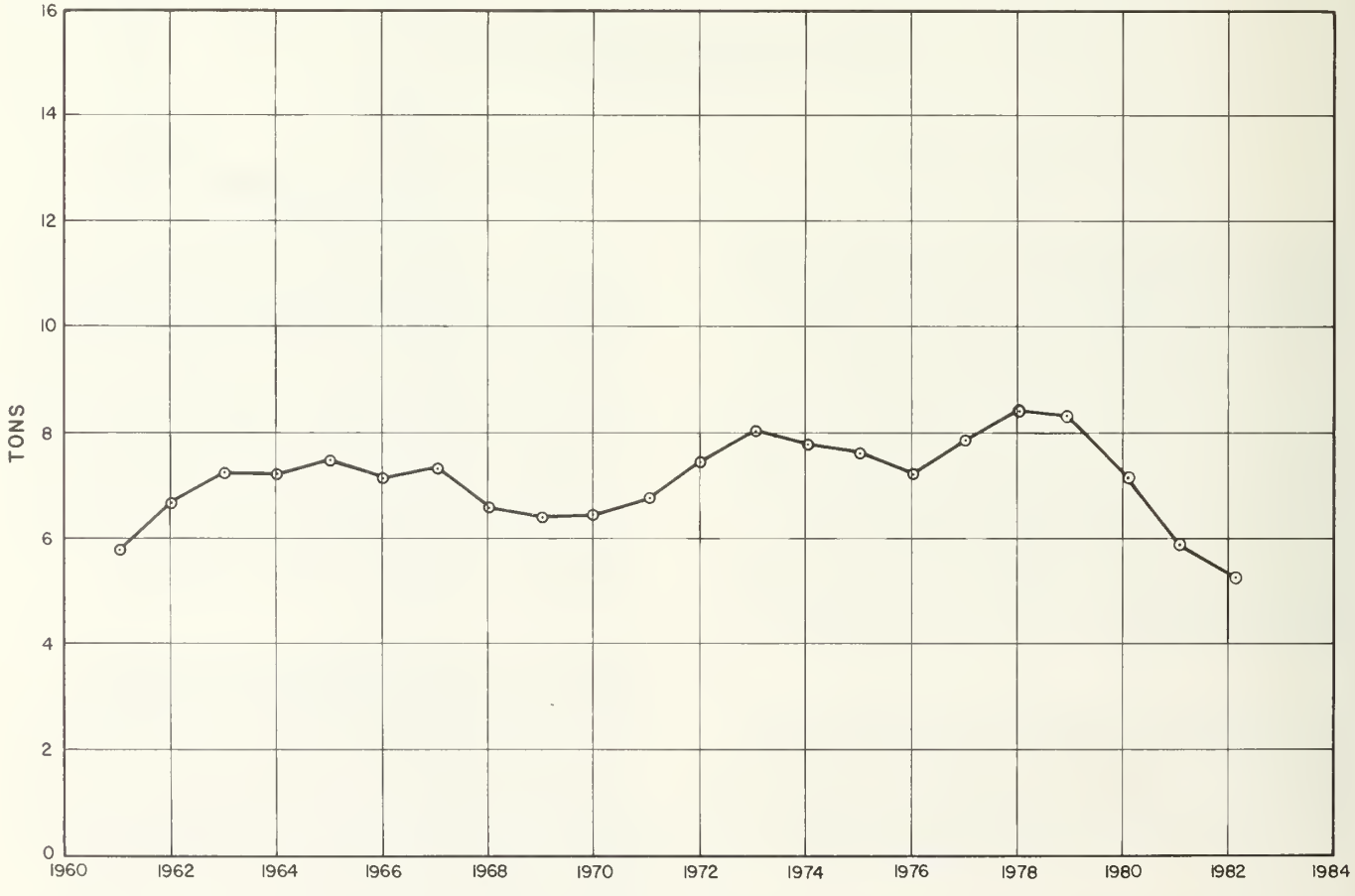


Figure 5. Annual per capita consumption of aggregate in the Fresno P-C Region. Based on population and 3 year averages of production, as shown on Figure 6.

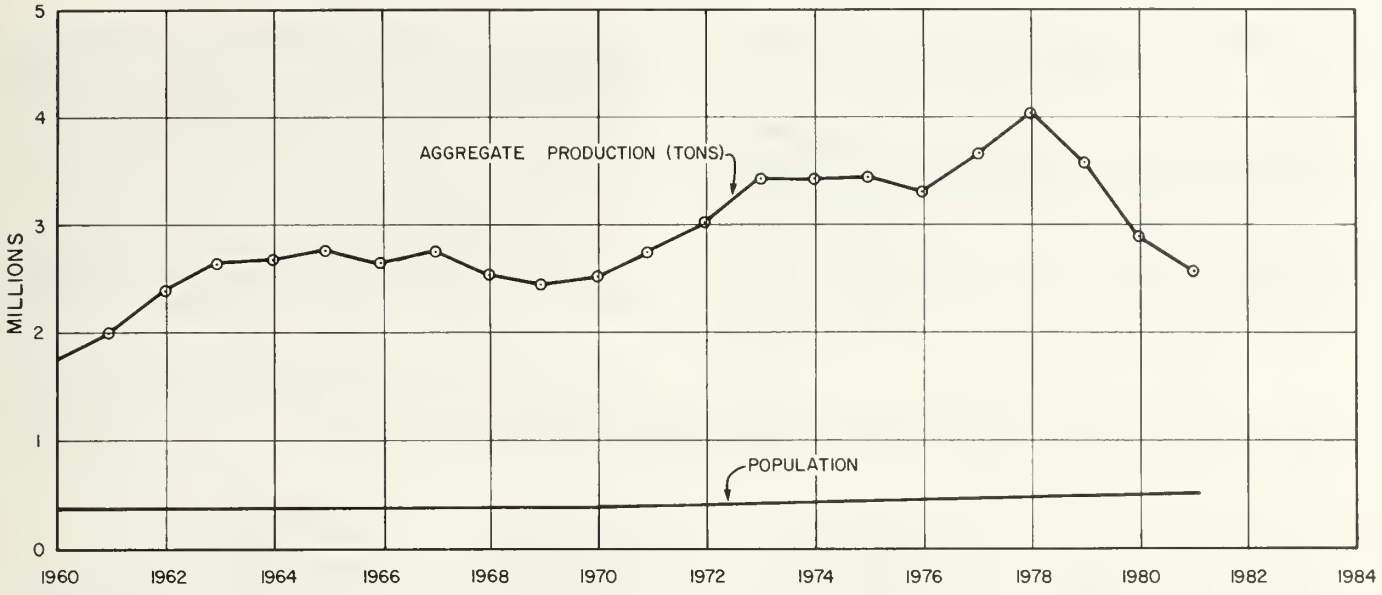


Figure 6. Fresna P-C Regian: Papulatian and aggregate production records for years 1960-83. Annual aggregate praduction has been smaathed thraugh use af a 3-year ralling average.

TABLE 7 — Population, aggregate consumption and per capita consumption in the Fresno P-C Region during the period 1960-1983.

YEAR	POPULATION	AGGREGATE CONSUMPTION (rounded to nearest 1,000 tons)	3-YEAR AVERAGE OF CONSUMPTION (tons)	ANNUAL PER CAPITA CONSUMPTION (tons)
1960	351,400	1,774,000		
1961	355,600	2,017,000	2,051,000	5.77
1962	359,900	2,362,000	2,334,000	6.60
1963	364,100	2,623,000	2,529,000	6.95
1964	368,400	2,602,000	2,527,000	6.86
1965	372,600	2,356,000	2,720,000	7.30
1966	376,900	3,202,000	2,656,000	7.05
1967	381,100	2,409,000	2,777,000	7.29
1968	385,400	2,720,000	2,536,000	6.58
1969	389,600	2,480,000	2,473,000	6.35
1970	393,900	2,218,000	2,533,000	6.43
1971	404,100	2,900,000	2,718,000	6.73
1972	414,200	3,036,000	3,092,000	7.47
1973	424,400	3,339,000	3,405,000	8.02
1974	434,500	3,840,000	3,403,000	7.83
1975	444,700	3,031,000	3,413,000	7.68
1976	454,900	3,369,000	3,306,000	7.27
1977	465,000	3,517,000	3,679,000	7.91
1978	475,200	4,150,000	4,012,000	8.44
1979	485,300	4,368,000	4,077,000	8.40
1980	495,500	3,714,000	3,573,000	7.21
1981	505,600	2,636,000	2,902,000	5.74
1982	515,800	2,356,000	2,563,000	4.97
1983	526,000	2,695,000		

Average annual per capita consumption for 1961-1982 is 7.04 tons per person per year.
Calculations may not replicate precisely due to rounding.

Comparison of the 50-Year Aggregate Demand with Current Reserves

The total PCC-grade aggregate reserves for the Fresno P-C Region were estimated to be 119.3 million tons (this figure does not reflect reserve depletion by any producers since December 1984). At the average rate of past aggregate consumption in the region (7 tons per person annually), these reserves are theoretically sufficient to satisfy the total aggregate demands of the P-C region to mid-2010.

According to U.S. Bureau of Mines aggregate production statistics for the years 1960 to 1983 and information from aggregate operators in the P-C region, roughly 50 percent of the total aggregate consumed in the study region has been PCC-grade. If the region continues to require the same percentage of PCC-grade aggregate, the total amount of PCC-grade aggregate that would be needed to supply the Fresno area through the year 2034 is estimated to be 134 million tons. Thus, in addition to the current reserves, 14.7 million tons of PCC-grade aggregate will be needed to supply the projected needs for this commodity in the Fresno P-C Region for the next 50 years.

TABLE 8. Projected aggregate consumption through the year 2034 for the Fresno P-C Region. Five-year per capita consumption = 35.2 tons/person (One-year per capita consumption = 7.0 tons/person).

YEARS	*AVERAGE POPULATION (millions)	AGGREGATE CONSUMPTION ALL AGGREGATE (million tons)	AGGREGATE** CONSUMPTION PCC AGGREGATE (million tons)
1985-1989	.576	20.3	10.2
1990-1994	.625	22.0	11.0
1995-1999	.670	23.6	11.8
2000-2004	.710	25.0	12.5
2005-2009	.747	26.3	13.2
2010-2014	.785	27.6	13.8
2015-2019	.822	28.9	14.4
2020-2024	.860	30.3	15.1
2025-2029	.898	31.6	15.8
2030-2034	.931	32.8	16.4
TOTAL		268.4	134.2

*Population projections for the years 1985-2020 were obtained from the California Department of Finance Report 83-P-3. Population projections for the years 2021-2034 were linearly projected from data in Report 83-P-3.

**This estimate is based on the fact that approximately 50 percent of the aggregate consumed from 1960 to 1980 was PCC quality.

ALTERNATIVE SOURCES OF AGGREGATE

Potential sources of aggregate, in addition to the deposits classified MRZ-2, exist within the Fresno P-C Region. These potential sources lie within areas that are classified MRZ-3 and include areas underlain by Quaternary alluvial deposits, Tertiary sedimentary and volcanic rocks, and pre-Cretaceous intrusive and metamorphic basement rocks.

Potential Alluvial PCC-Grade Aggregate

Alluvium classified MRZ-3 includes Quaternary stream channels and alluvial fans built by the San Joaquin and Kings rivers prior to Recent time. The modern rivers have dissected these deposits — forming the bluffs along both channels — while developing their current grade and course. These deposits were probably built over a period of one million years or more, in response to the glaciation of the Sierra Nevada Mountains (Marchand, 1976). The source rocks and the energy of the depositional environment may have varied as the drainage basin developed and evolved. Such changes will cause variability in the hardness, lithic and mineralogic composition, grain size and shape, and sorting of the alluvium. Furthermore, the difference in composition and age will cause variances in the degree of weathering of the alluvium. Thus, though sand and gravel exist within these units, their suitability as concrete aggregate is questionable and variable. None of this material is known to have been used for PCC in the Fresno area. However, beds in the Modesto and Riverbank formations have been utilized for PCC aggregate in Sacramento. As is obvious from Plate 2, a tremendous volume of material is included in these older deposits. Much of this volume consists of sand that may be coarse enough for PCC-grade aggregate. Proper testing and beneficiating may prove that suitable aggregate is available from these formations in the Fresno area.

Part of the Fresno P-C Region classified MRZ-3 is underlain by an unnamed Tertiary gravel unit which marks the course of the San Joaquin River in Miocene time, about 5 to 23 million years ago (Marchand, 1976). It crops out intermittently along the eastern side of the P-C region from approximately one mile north of Dry Creek south to Copper Avenue (on the Friant quadrangle), and south of China Garden (on the Daulton quadrangle).

The gravel also crops out on the west side of Little Table Mountain and east of Highway 41, between Road 204 and Avenue 12. This might provide a suitable source of sand and gravel or sand and crushed rock, but because of its age, its durability may be low. It is in part tuffaceous, so careful site-specific evaluation is required.

A second late Tertiary unit, mapped as the North Merced Gravel (Marchand and Allwardt, 1978), may also provide suitable aggregate. It is a Pliocene or Pleistocene deposit of lag gravels on an erosion surface and is found on the northern and western slopes of Little Table Mountain. Thickness of the deposit is unknown, as is rock quality. Neither this nor the previously discussed Tertiary gravel have been historically mined, so data to evaluate their suitability as PCC-grade aggregate is lacking.

Potential Crushed Rock Aggregate

It is important to note that crushed rock may be significant in this area for the future. Sand sources are abundant within and adjacent to the Fresno P-C Region in both active streams and in the bluffs and fans. However, the coarse aggregate fraction is in much shorter supply. As the gravel supplies are depleted, the more abundant sand could be mixed with crushed rock. Basement rocks of the Sierra Nevada crop out along the eastern side of the P-C region, adjacent to the Friant Kern and Madera canals. Within the P-C region the basement rock consists of granodiorite and metasedimentary rocks (Matthews and Burnett, 1965) which may be a suitable source for crushed rock aggregate. Metavolcanics, meta-gabbro, granite, tonalite, and diorite can be found within 10 miles of the P-C region, and could represent additional exploration targets for quarry sites.

Another source of crushed rock is the oversized cobbles and boulders of the Kings River. This material is concentrated upstream from a point below Avocado Lake. It is a potentially important alternate source of PCC-grade aggregate because blasting will not be required to diminish the rock.

Potential Sources of PCC-Grade Aggregate Outside the P-C Region

PCC-grade aggregate could be obtained for use in the Fresno P-C Region from active resource areas outside the P-C region. The closest of these resource areas, which are 50 miles from downtown Fresno, are shown on Table 9. The additional transport costs (see Table 2) incurred by bringing in aggregate from these other sites would substantially increase the price of construction materials for the Fresno consumer. Utilization of these deposits by the Fresno market could cause supply problems in the urbanizing areas they already serve.

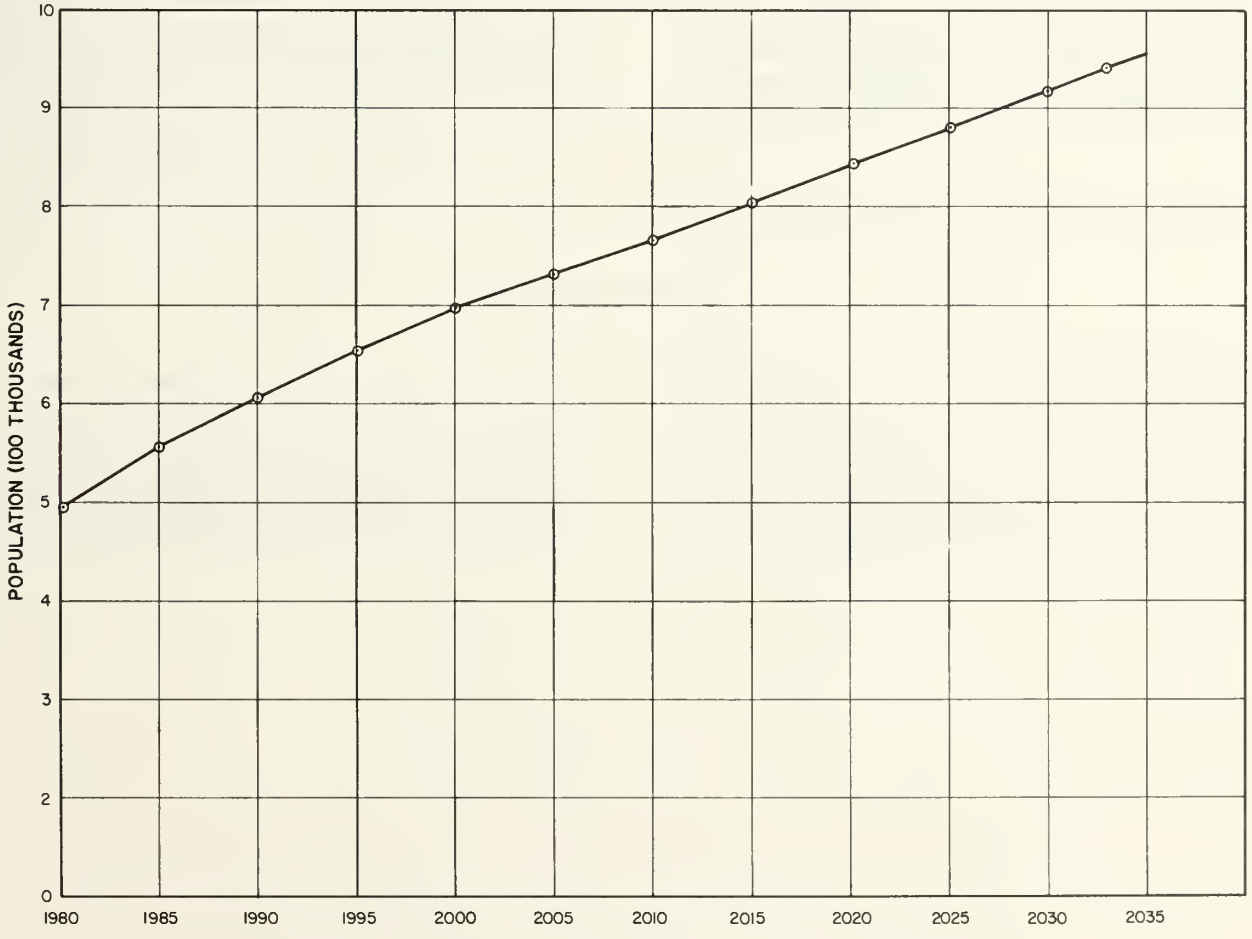


Figure 7. Projected population (50 years from date of study) of the Fresno P-C Region.

TABLE 9. Transport distance from the active deposits nearest the Fresno P-C Region.

AREA	COUNTY	*DISTANCE FROM DOWNTOWN FRESNO	INCREASE IN HAUL DISTANCE OVER LOCAL DEPOSITS	ADDITIONAL COST PER TON FOR TRANSPORT
Maripasa Creek	Merced	50	40	$3.68
Kaweah River	Tulare	50	40	$3.68
Caalinga	Fresno	60	50	$4.53
Los Banas	Merced	70	60	$5.95
Merced River	Merced	80	70	$6.34

*Rounded to nearest ten miles; measured along major roads.

CONCLUSIONS

Within the Fresno P-C Region, two sectors, subdivided into 65 subsectors, have been identified that contain in excess of 2.1 billion tons of aggregate resources.

Based upon available production data and population projections, the Fresno P-C Region will need 268.4 million tons of aggregate during the next 50 years. Of this projected demand, approximately 50 percent (approximately 134 million tons) must be suitable for Portland cement concrete. The approximately 119 million tons of aggregate reserves determined to exist within the P-C region amount to only 44 percent of the projected demand over the next 50 years. Unless new resources are permitted for mining, or alternative resources are utilized, existing reserves will be depleted during the year 2010. If a major earthquake were to affect the P-C region and necessitate reconstruction, the depletion date of existing reserves will arrive before 2010.

ACKNOWLEDGMENTS

The Division of Mines and Geology gratefully acknowledges the full cooperation of local government agencies, organizations, and aggregate producers, all of whom provided information during the course of this study. Special thanks are extended to John Buada, James White, the Fresno County Planning and Resources and Development Departments, Madera County Planning Department, Central Valley Rock Products Association, Kings River Conservation District, California Department of Transportation – District 6, California Department of Water Resources, Brueckner Sand and Gravel, Central Valley Ready-Mix, Granite Construction Company, Lonestar Industries, River Rock Products (Builders Concrete), Sanger Rock and Sand (Clovis Ready-Mix), San Joaquin Rock and Sand (Talley Concrete), Sequoia Rock Company, and Stewart and Nuss, Inc.

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APPENDIX

Interim Criteria for Sectorization of MRZ-2 Areas for Aggregate

The purpose of sectorizing MRZ-2 areas is to provide a semi-quantified estimate of construction aggregate resources which are likely to be available to satisfy society's needs during the next 50 years. This estimate, when compared to DMG projected needs for the next half century, provides the context for communities to plan for future resource availability in their land-use policies. The determination of sectors is intended for the use of the State Mining and Geology Board in identifying areas that are candidates for designation under SMARA. The development of sectors provides a perception of future mineral resource availability in the face of future needs and also portrays where these available minerals are generally located. This information is distributed by the Board to all affected lead agencies to provide them with the data necessary to plan for future resource availability in their land-use policies.

Areas within MRZ-2 classifications are sectorized if they have current land uses which are similar to those in areas which have undergone mineral extraction in the past. Areas within MRZ-2 classifications which have generally not been available for surface mining in the past for specified social or economic reasons are not sectorized. Since such areas are unlikely to be used for surface mining during the foreseeable future, their inclusion in estimates of future resource availability would be misleading.

The estimation of future mineral resource availability in sectors is not a precise analysis, but rather is the best general estimate which can be made with the data presently available. Areas within and without sectors can be used for mining or other land uses at the discretion of the local governments which are charged with responsibility for making land-use decisions. Establishment of sectors in no way infringes on this authority. Rather, it provides a perception of future mineral resource availabilities in the face of future needs and also portrays where these available minerals are generally located.

The following criteria were used by DMG in identifying mineral resource areas which are available for future use. These criteria, in conjunction with the geologic and geometric characteristics of specific mineral deposits, were used in sectorizing MRZ-2 areas. Use of these criteria assures that sectors contain geologically homogenous mineral deposits which, based upon current land use, will be available for future use.

The following specific land uses are considered to be generally incompatible with mining and have been excluded from sectorized lands. Mineral resource areas containing land uses not specifically listed will be considered for sectorization. The criteria are to be applied only to lands classified MRZ-2.

There are two general categories of exclusion: (I.) Economic Exclusion, and (II.) Social Exclusion.

I. *Economic Exclusion*
Specific excluded land uses are:

1. Residential areas
2. Commercial areas with land improvements (buildings)
3. Industrial areas (buildings and adjacent needed storage and parking facilities)
4. Major public or private engineering projects, including:

   a. canals
   b. freeways
   c. bridges
   d. airports and associated developments such as parking lots
   e. dams
   f. railroads
   g. major pipelines
   h. major power transmission lines

II. *Social Exclusion*
Specific excluded land uses are:

1. Cemeteries,
2. Geologic scientific zones,
3. Public parks, developed historical sites and structures, and public recreation areas of all types,*
4. Public or private schools, institutions, hospitals, and prisons, including adjacent grounds and related structures,
5. Military bases and reservations.

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* *NOTE:* Since the development of these interim criteria, a policy change regarding parklands has occurred. Parklands are now sectorized if they are not excluded on the basis of economic criteria. Sectorized parklands are, however, treated separately in the classification reports, and their mineral resources are not mixed with those occurring on other types of land.

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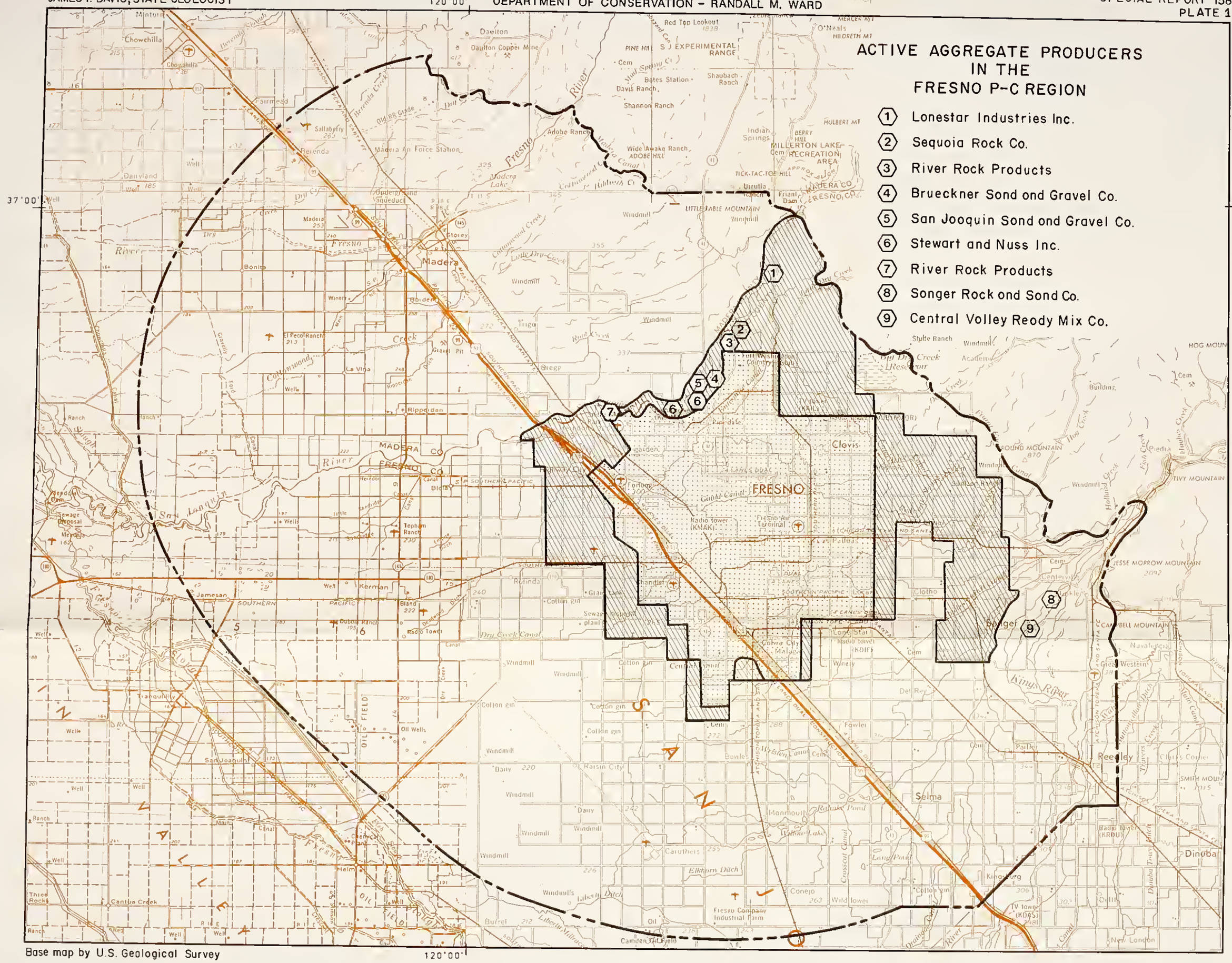

EXPLANATION

Production-Consumption Region Boundary. Includes resource areas and the area they serve. Eastern boundary follows break in slope between foothills and the Sierra Nevada Mountains, and census tract boundaries.

Areas identified by the Office of Planning and Research (OPR) which are either urbanized or projected to urbanize (urbanizing areas) by the year 1990.

Boundary of area identified in this study as urbanizing. Changes from the OPR line incorporate growth since the OPR's study in 1975 and land-use plans of the local agencies.

FRESNO P-C REGION

FRESNO AND MADERA COUNTIES, CALIFORNIA

by

Judy Wiedenheft Cole and David R. Fuller

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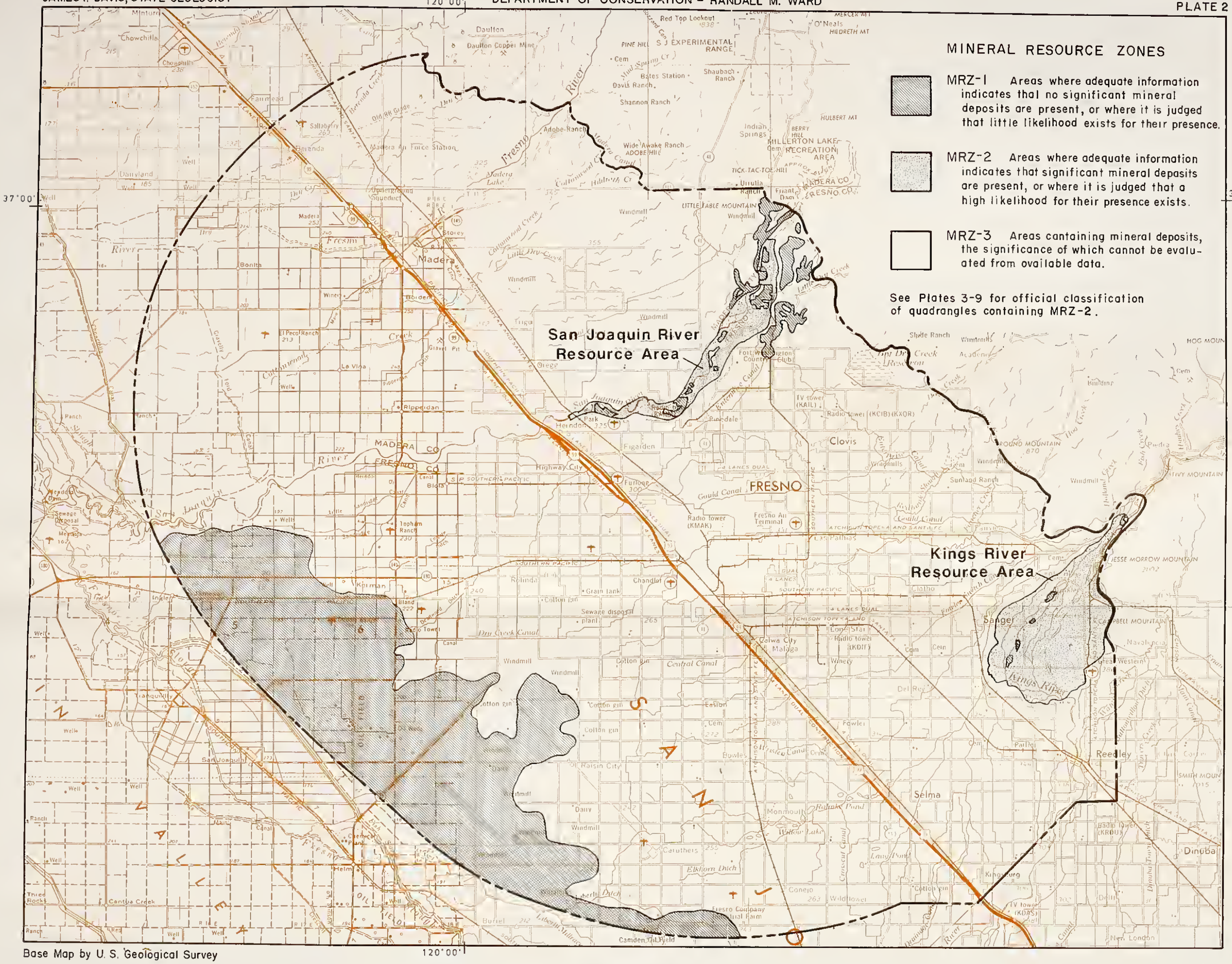
PLATE 2



Base Map by U. S. Geological Survey

MINERAL LAND CLASSIFICATION OF AGGREGATE RESOURCES IN THE FRESNO P-C REGION

FRESNO AND MADERA COUNTIES, CALIFORNIA

by
Judy Wiedenheft Cole and David R. Fuller

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PLATE 3

TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

EXPLANATION

- Drill hole
- PRODUCTION-CONSUMPTION REGION BOUNDARY (see text for discussion)
- MINERAL RESOURCE ZONE BOUNDARIES
  - MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence
  - MRZ-2 Areas where adequate information indicates that significant mineral deposits are present, or where it is judged that a high likelihood for their presence exists
  - MRZ-3 Areas containing mineral deposits the significance of which cannot be evaluated from available data
  - MRZ-4 Areas where available information is inadequate for assignment to any other mineral resource zone.

SAND & GRAVEL
MRZ-2

See text for additional explanation of MRZ symbols

A — A' GEOLOGIC CROSS-SECTION LINE
Arrow at end of line indicates section continues onto adjacent quadrangle

LANES BRIDGE, CALIF.

MINERAL LAND CLASSIFICATION MAP

AGGREGATE RESOURCES ONLY

Fresno P-C Region

By

Judy Wiedenheft Cole and David R. Fuller

1985

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

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FRIANT QUADRANGLE

SPECIAL REPORT 158
PLATE 4

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TOPOGRAPHIC BASE MAP BY U S GEOLOGICAL SURVEY
Reduced from 1:24,000

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

FRIANT, CALIF.

EXPLANATION

- Drill hole
- PRODUCTION-CONSUMPTION REGION BOUNDARY (see text for discussion)
- MINERAL RESOURCE ZONE BOUNDARIES
  - MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence
  - MRZ-2 Areas where adequate information indicates that significant mineral deposits are present, or where it is judged that a high likelihood for their presence exists
  - MRZ-3 Areas containing mineral deposits the significance of which cannot be evaluated from available data.
  - MRZ-4 Areas where available information is inadequate for assignment to any other mineral resource zone.
- SAND & GRAVEL / MRZ-2
- A' — A'' GEOLOGIC CROSS-SECTION LINE
  Arrow at end of line indicates section continues onto adjacent quadrangle

See text for additional explanation of MRZ symbols

MINERAL LAND CLASSIFICATION MAP

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HERNDON QUADRANGLE

SPECIAL REPORT 158
PLATE 5

MRZ-3

MRZ-2

MRZ-1

Herndon

Highway City

TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

EXPLANATION

- Drill hole
- PRODUCTION-CONSUMPTION REGION BOUNDARY (see text for discussion)
- MINERAL RESOURCE ZONE BOUNDARIES
- SAND & GRAVEL
- MRZ-2

MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present or where it is judged that little likelihood exists for their presence.

MRZ-2 Areas where adequate information indicates that significant mineral deposits are present or where it is judged that a high likelihood for their presence exists.

MRZ-3 Areas containing mineral deposits the significance of which cannot be evaluated from available data.

MRZ-4 Areas where available information is inadequate for assignment to any other mineral resource zone.

See text for additional explanation of MRZ symbols

HERNDON, CALIF.

MINERAL LAND CLASSIFICATION MAP

AGGREGATE RESOURCES ONLY

Fresno P-C Region

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FRESNO NORTH QUADRANGLE
SPECIAL REPORT 158
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TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

EXPLANATION

- Drill hole
- PRODUCTION-CONSUMPTION REGION BOUNDARY (see text for discussion)

MINERAL RESOURCE ZONE BOUNDARIES

SAND & GRAVEL
MRZ-2

- MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence
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- MRZ-3 Areas containing mineral deposits the significance of which cannot be evaluated from available data
- MRZ-4 Areas where available information is inadequate for assignment to any other mineral resource zone.

See text for additional explanation of MRZ symbols

FRESNO NORTH, CALIF

MINERAL LAND CLASSIFICATION MAP

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Fresno P-C Region

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TOPOGRAPHIC BASE MAP BY U S GEOLOGICAL SURVEY
Reduced from 1:24,000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

PIEDRA, CALIF

EXPLANATION

- Drill hole
- PRODUCTION-CONSUMPTION REGION BOUNDARY (see text for discussion)
- MINERAL RESOURCE ZONE BOUNDARIES
- SAND & GRAVEL
- MRZ-2

MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence

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MRZ-3 Areas containing mineral deposits the significance of which cannot be evaluated from available data

MRZ-4 Areas where available information is inadequate for assignment to any other mineral resource zone

See text for additional explanation of MRZ symbols

MINERAL LAND CLASSIFICATION MAP

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Fresno P-C Region

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SANGER QUADRANGLE

SPECIAL REPORT 158
PLATE 8

TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

SANGER, CALIF.

EXPLANATION

- Drill hole
- PRODUCTION-CONSUMPTION REGION BOUNDARY (see text for discussion)

MINERAL RESOURCE ZONE BOUNDARIES

SAND & GRAVEL
MRZ-2

- MRZ-1 Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence
- MRZ-2 Areas where adequate information indicates that significant mineral deposits are present, or where it is judged that a high likelihood for their presence exists
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See text for additional explanation of MRZ symbols

D — D' GEOLOGIC CROSS-SECTION LINE
Arrow at end of line indicates section continues onto adjacent quadrangle

MINERAL LAND CLASSIFICATION MAP

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Fresno P-C Region

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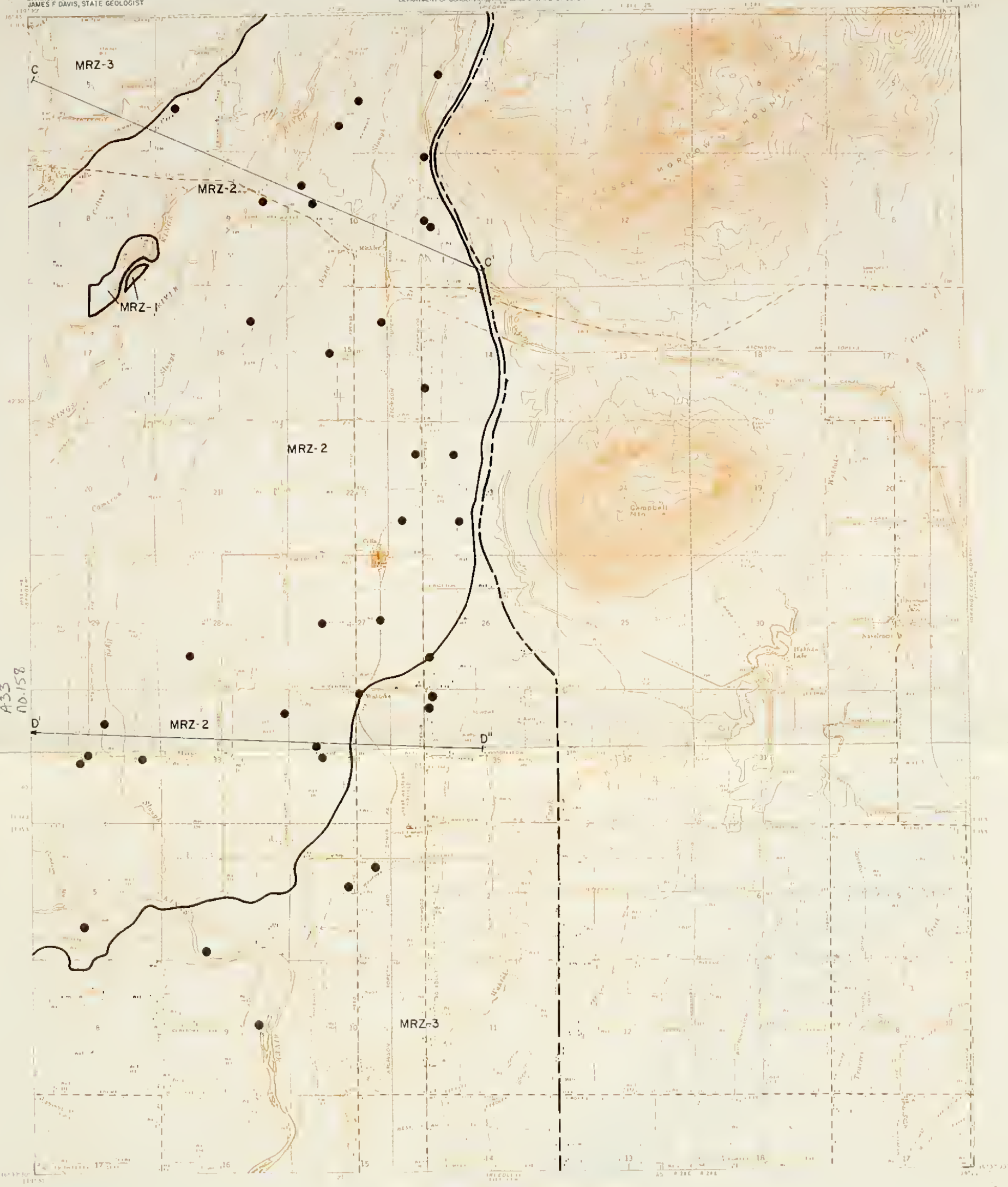
WAHTOKE QUADRANGLE
SPECIAL REPORT 158
PLATE 9



TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

- Drill hole
- PRODUCTION CONSUMPTION REGION BOUNDARY (see text for discussion)

MINERAL RESOURCE ZONE BOUNDARIES

SAND & GRAVEL
MRZ-2

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See text for additional explanation of MRZ symbols

C — C' GEOLOGIC CROSS-SECTION LINE
Arrow at end of line indicates section continues onto adjacent quadrangle

WAHTOKE, CALIF

MINERAL LAND CLASSIFICATION MAP

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Fresno P-C Region

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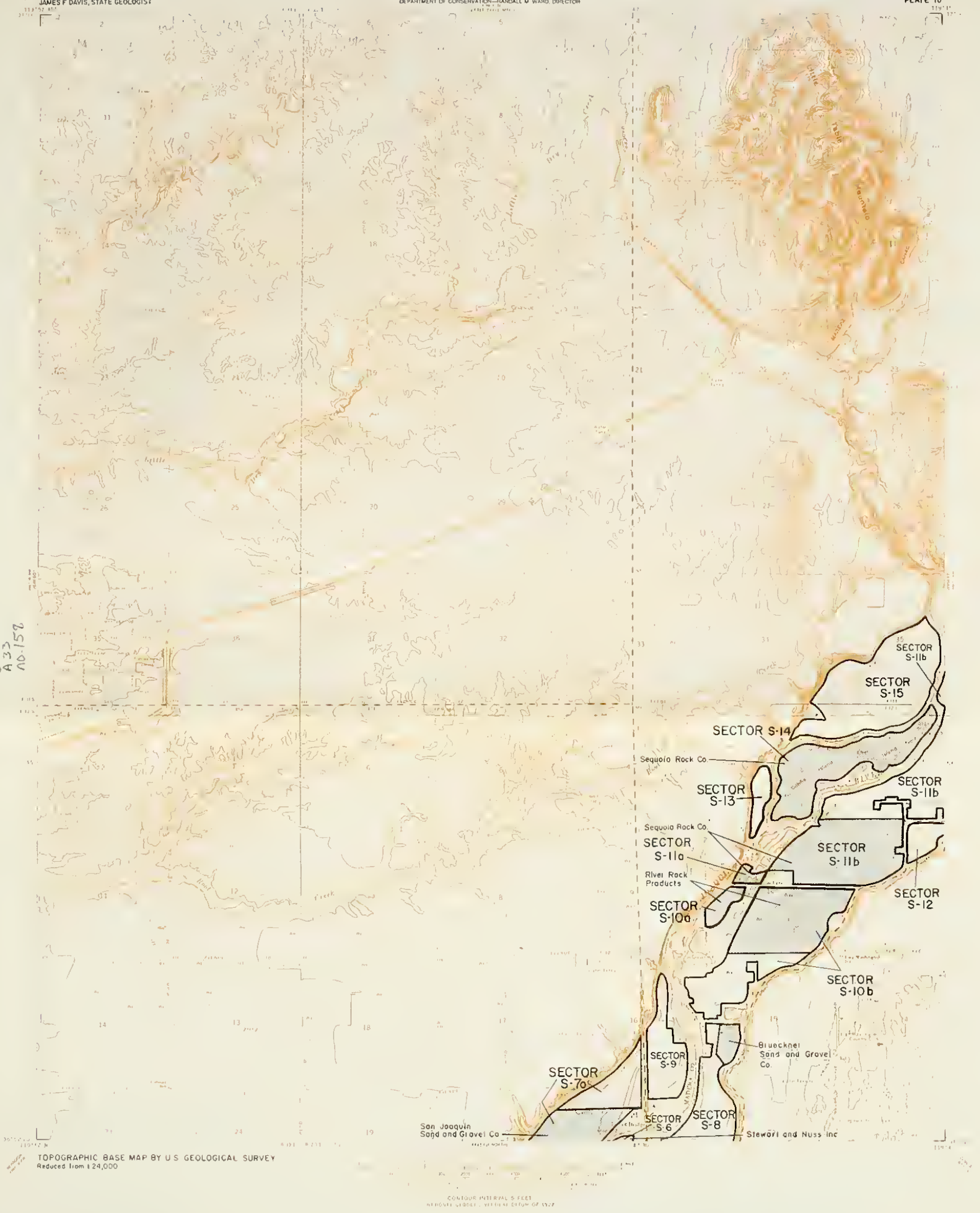
LANES BRIDGE QUADRANGLE

SPECIAL REPORT 158
PLATE 10



TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

LANES BRIDGE, CALIF

EXPLANATION

Sector boundory

Properties owned or controlled by aggregate producers

AGGREGATE RESOURCE SECTORS

Fresno P-C Region

By

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FRIANT QUADRANGLE

SPECIAL REPORT 158
PLATE 11

SECTOR S-20

NOT IN SECTOR

B.W.B. Ranch
(C.U.P. for aggregate mining granted 10/85)

SECTOR S-19

Lonestar Industries Inc.

SECTOR S-18a

SECTOR S-18b

SECTOR S-17

SECTOR S-16

Lonestar Industries Inc.

SECTOR S-11b

SECTOR S-12

TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

FRIANT, CALIF.

EXPLANATION

Sector boundory

Properties owned or controlled by oggregote producers

AGGREGATE RESOURCE SECTORS

Fresno P-C Region

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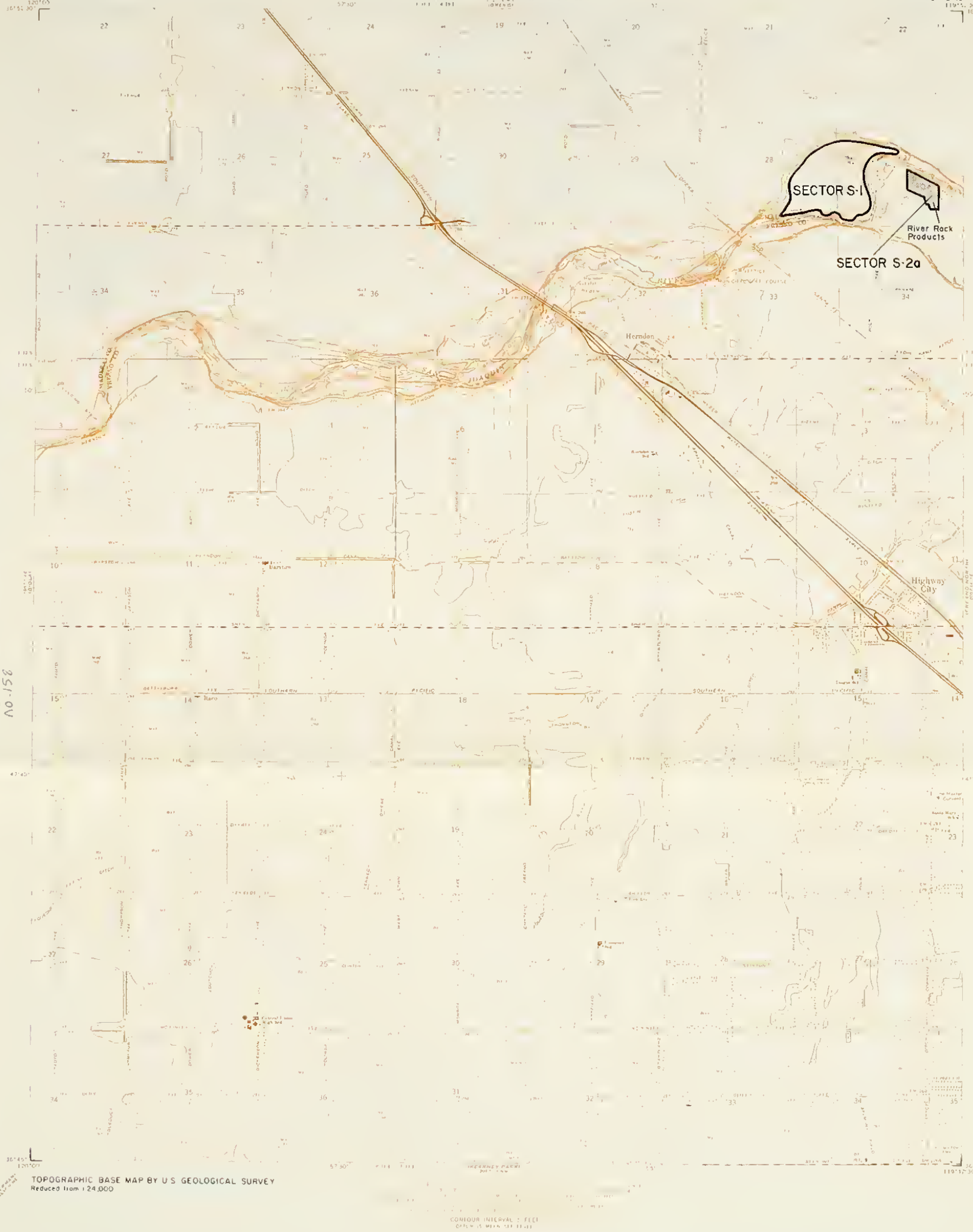
HERNDON QUADRANGLE

SPECIAL REPORT 158
PLATE 12



TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

EXPLANATION

Sector boundory

Properties owned or controlled by oggregate producers

N

HERNDON, CALIF

AGGREGATE RESOURCE SECTORS

Fresno P-C Region

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Judy Wiedenheft Cole and Dovid R. Fuller

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SECTOR S-2b
SECTOR S-3
SECTOR S-4
SECTOR S-5a
SECTOR S-5b
SECTOR S-5c
SECTOR S-6
SECTOR S-7a
SECTOR S-7b
SECTOR S-8
San Joaquin Sand & Gravel Co
Stewart & Nuss Inc
River Rock Products
Pinedale
Figarden
FRESNO

TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

FRESNO NORTH, CALIF

EXPLANATION

Sector boundory

Properties owned or controlled by aggregate producers

N

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Fresno P-C Region

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PIEDRA QUADRANGLE

SPECIAL REPORT 158
PLATE 14

TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY
Reduced from 1:24,000

CONTOUR INTERVAL 20 FEET

PIEDRA, CALIF.

EXPLANATION

Sector boundary

Properties owned or controlled by aggregate producers

AGGREGATE RESOURCE SECTORS

Fresno P-C Region

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SANGER QUADRANGLE

SPECIAL REPORT 158
PLATE 15

TOPOGRAPHIC BASE MAP BY U S GEOLOGICAL SURVEY
Reduced from 1:24,000

SANGER, CALIF

EXPLANATION

Sector boundary

Properties owned or controlled by aggregate producers

AGGREGATE RESOURCE SECTORS

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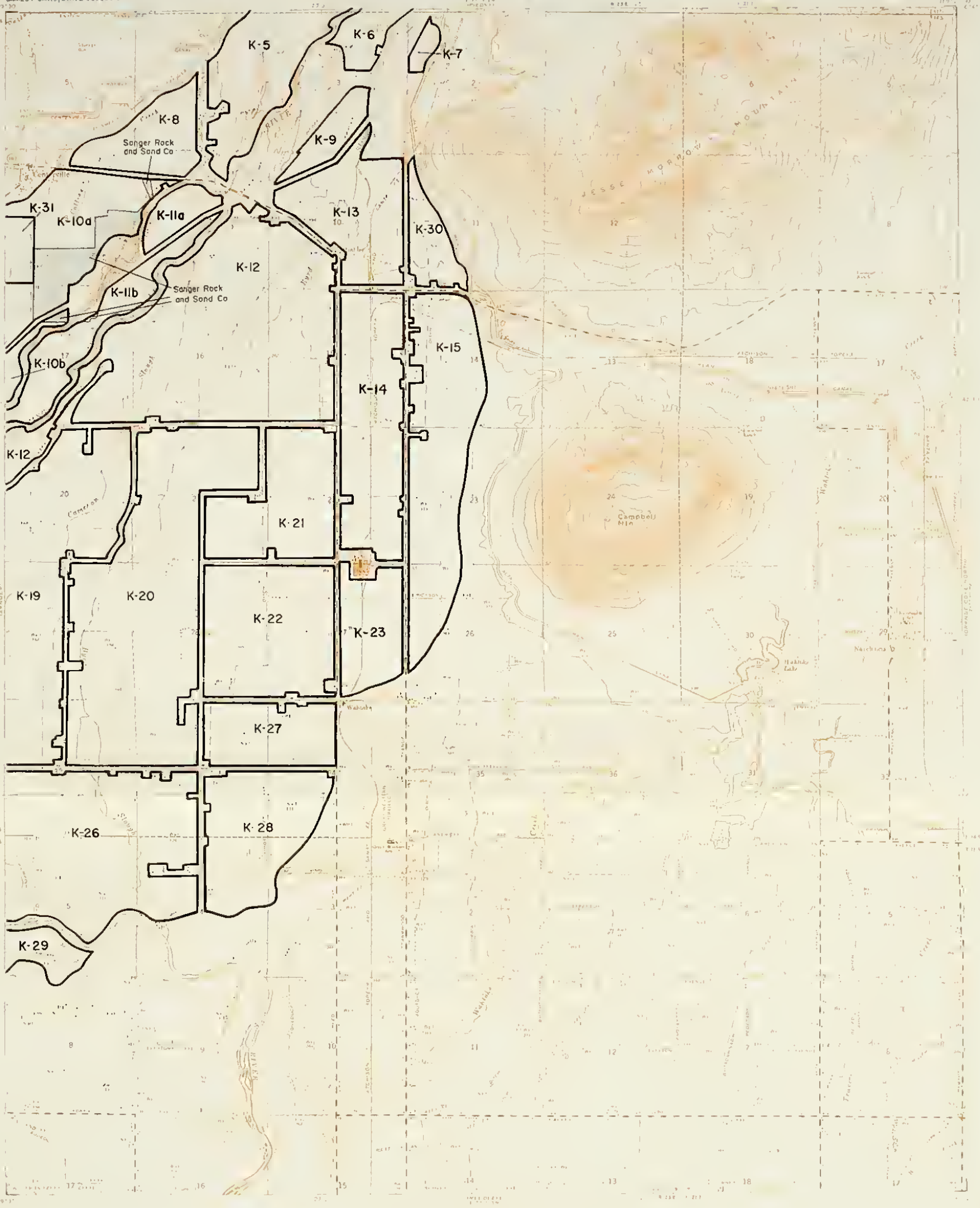
WAHTOKE QUADRANGLE
SPECIAL REPORT 158
PLATE 16



TOPOGRAPHIC BASE MAP BY U S GEOLOGICAL SURVEY
Reduced from 1:24,000

NOTE: Railroad tracks in subsectors K-13, K-14, K-15, and K-23 have been torn-up or abandoned.

CONTOUR INTERVAL 20 FEET

WAHTOKE, CALIF

EXPLANATION

Sector boundary

Properties owned or controlled by aggregate producers

AGGREGATE RESOURCE SECTORS

Fresno P-C Region

By

Judy Wiedenheft Cole and David R. Fuller

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SPECIAL REPORT 158
PLATE 17

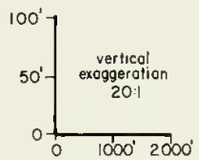
EXPLANATION

Quaternary Alluvial Deposits

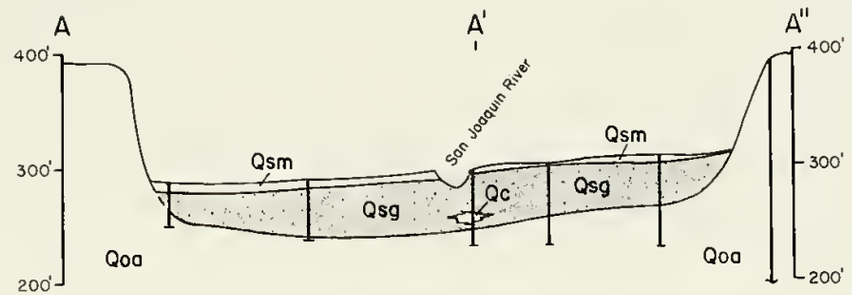
- Qal
  - Qsg — sand and gravel
  - Qsm — sand and silt
  - Qc — clay
- Qoa — alder alluvium (includes Modesto, Riverbank and Turlock Lake formations)

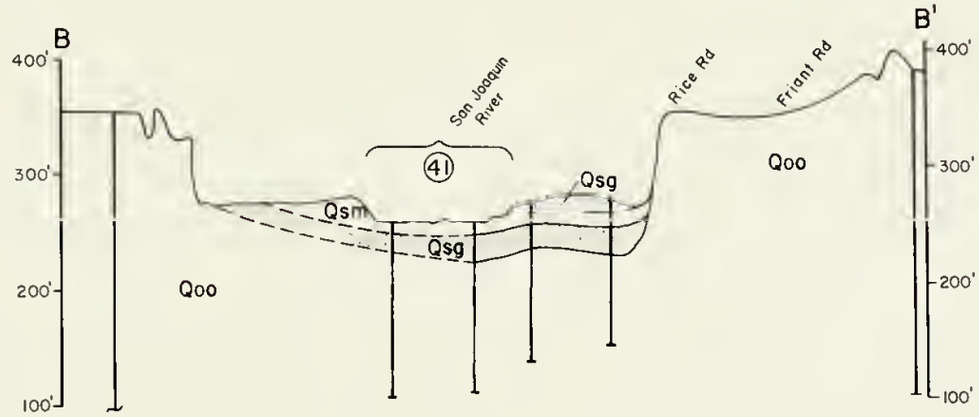
SYMBOLS

- contact: dashed where inferred
- drill hole: wavy crossarm indicates bottom of hole is below cross-section limit
- geologic units suitable for use as PCC-grade aggregate (MRZ-2 areas)



Refer to Plates 3 and 4 for location of cross-section lines





MINERAL LAND CLASSIFICATION OF THE FRESNO P-C REGION
GENERALIZED GEOLOGIC CROSS-SECTIONS A-A" & B-B'
SAN JOAQUIN RIVER

by
Judy Wiedenheft Cole and David R. Fuller

1986

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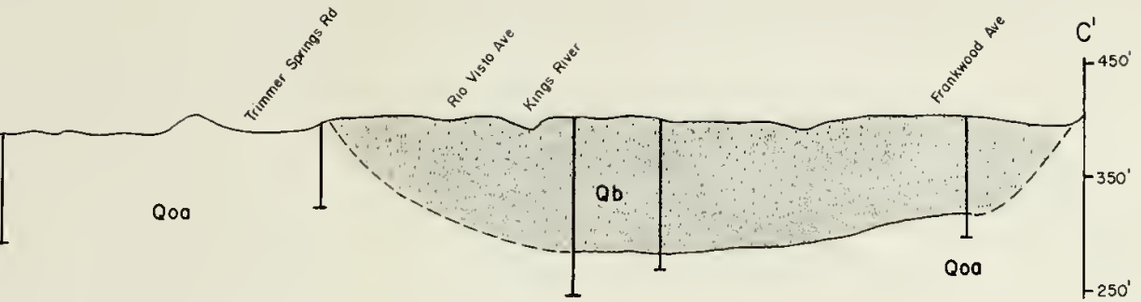
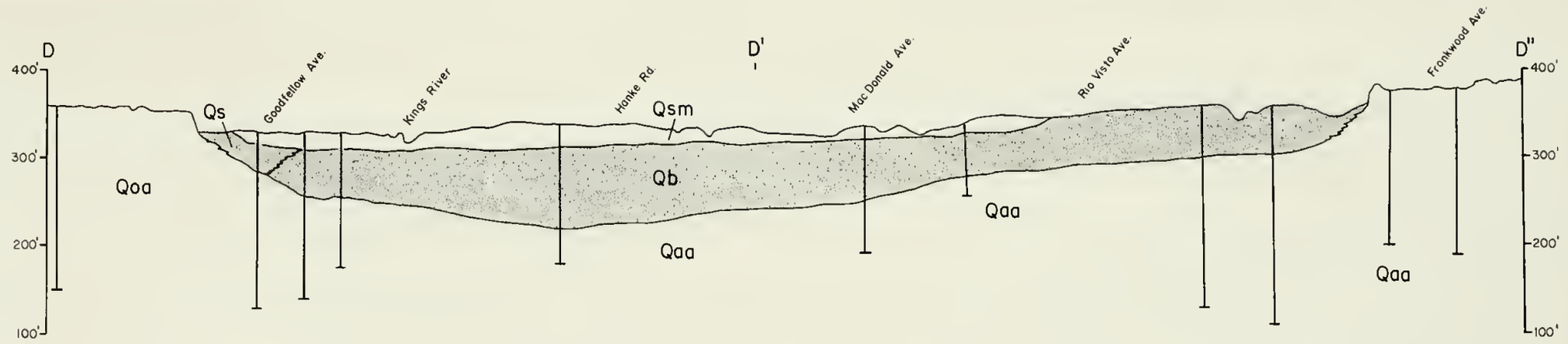




EXPLANATION

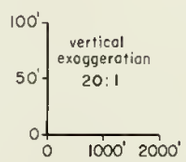
Quaternary Alluvial Deposits

Qal
- Qs sand
- Qb sand, gravel, and boulders
- Qsm sand and silt

Qoa older alluvium, undifferentiated

SYMBOLS

- contact: dashed where inferred
- drill hole
- geologic units suitable for use as PCC-grade aggregate (MRZ-2 areas)



Refer to Plates 8 and 9 for location of cross-sections

MINERAL LAND CLASSIFICATION OF THE FRESNO P-C REGION
GENERALIZED GEOLOGIC CROSS-SECTIONS C-C' & D-D"
KINGS RIVER

by

Judy Wiedenheft Cale and David R. Fuller

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